NASA Tech Briefs

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Space Administration

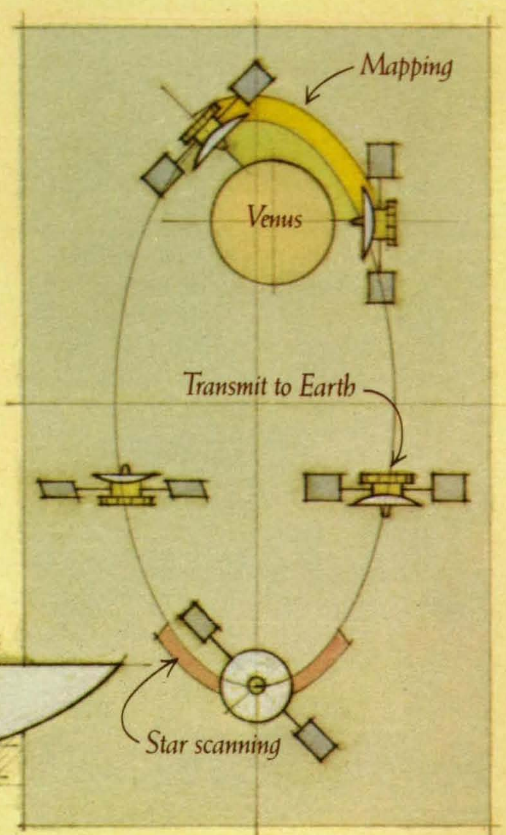
Transferring Technology to
American Industry
and Government

January 1990
Volume 14 Number 1

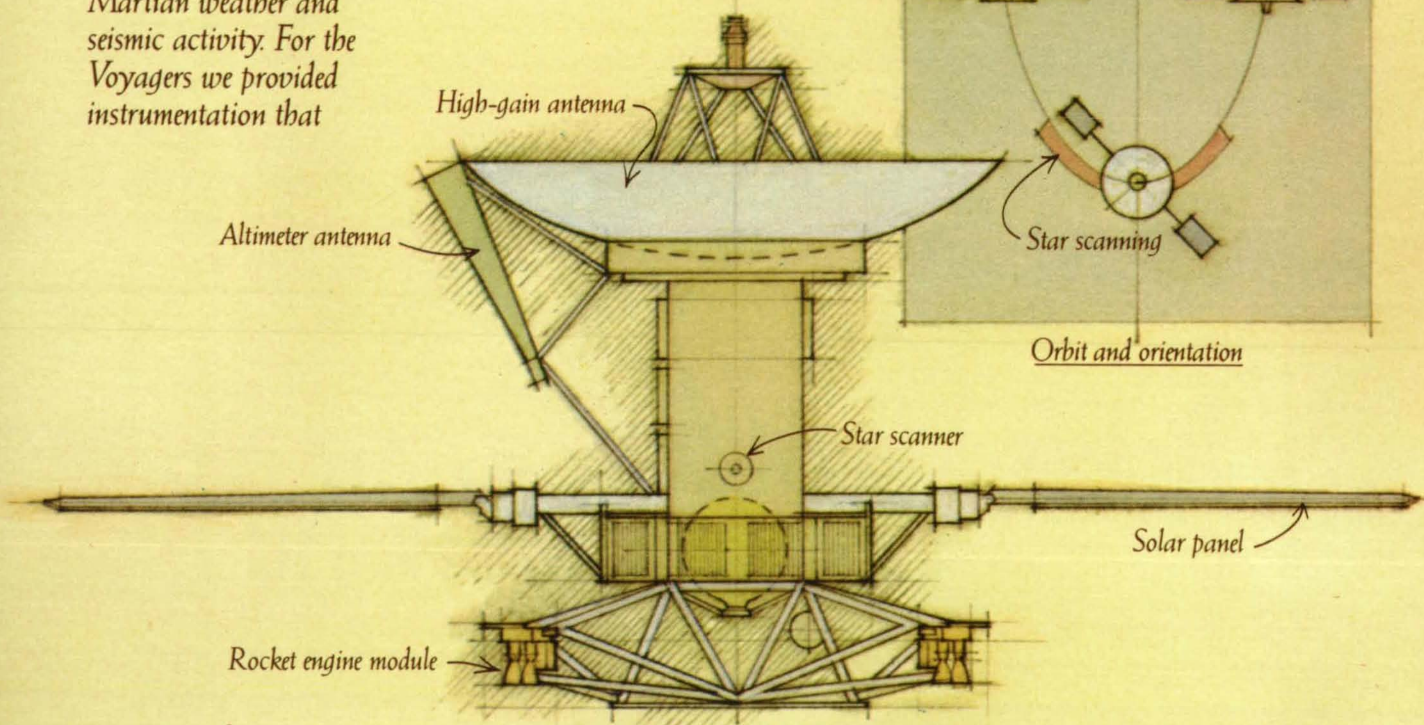
Mission To An Endangered World

In space: looking back to look forward.

What can the nature and origin of the universe tell us about the future of Earth? To help answer that question, we make craft and instruments for traveling billions of miles in space and seeing as far as 15 billion years back in time. Martin Marietta was the integrator and builder of two Viking landers, which sent back remarkable photos of the surface of Mars, examined soil samples, and studied Martian weather and seismic activity. For the Voyagers we provided instrumentation that reported on electromagnetic activity near Jupiter and Saturn–Voyager 2 went on to Uranus, some 2 billion miles from Earth. That was nine years after launch; next destination, Neptune, in 1989. These are but a few results of Martin Marietta's ability to create survivable, mystery-solving craft and their instruments–from concept through mission completion.



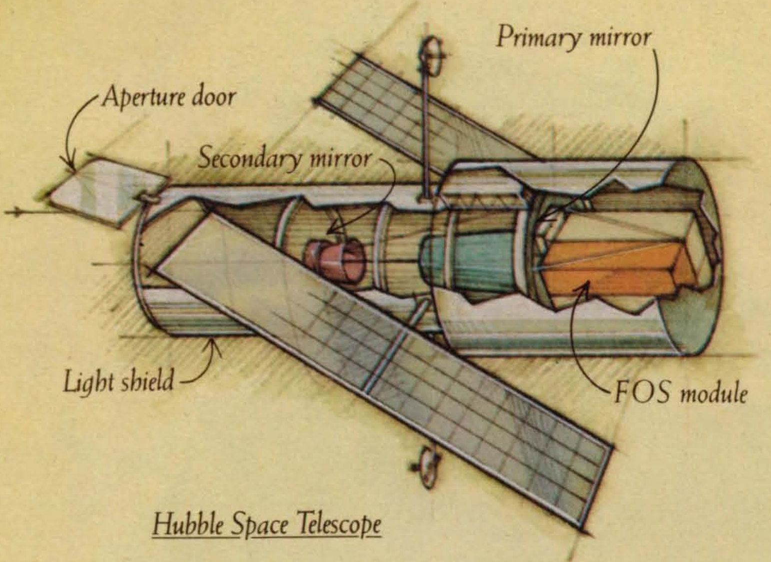
Orbit and orientation



Magellan Spacecraft

Mission: map Venus.

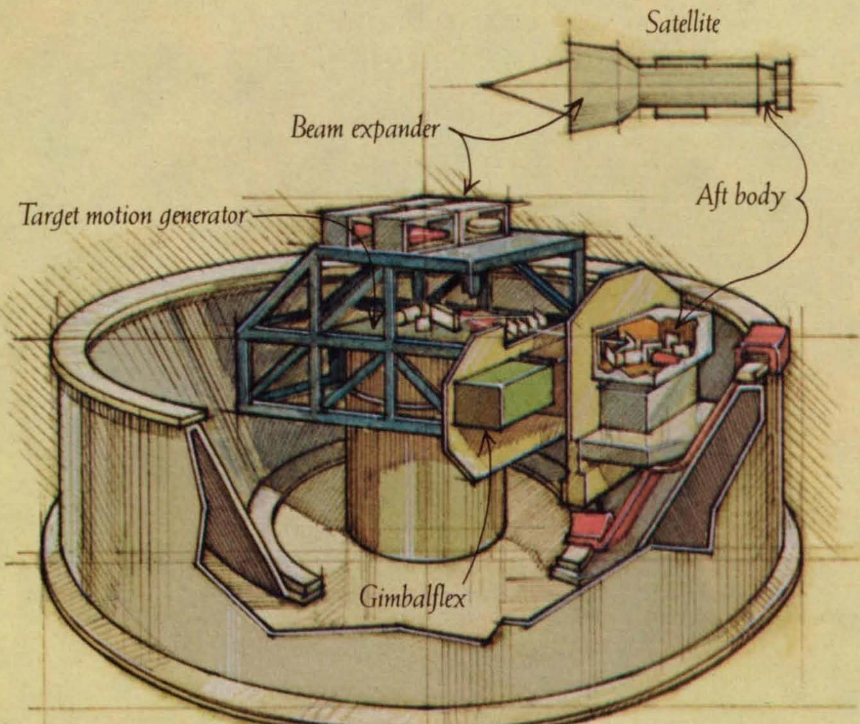
From orbit, Magellan's radar will penetrate the planet's thick, gaseous cloud cover and send back photo-like images of nearly 90% of its surface. Our role: design, integrate, build and test the craft.



Hubble Space Telescope

Viewing the infant universe.

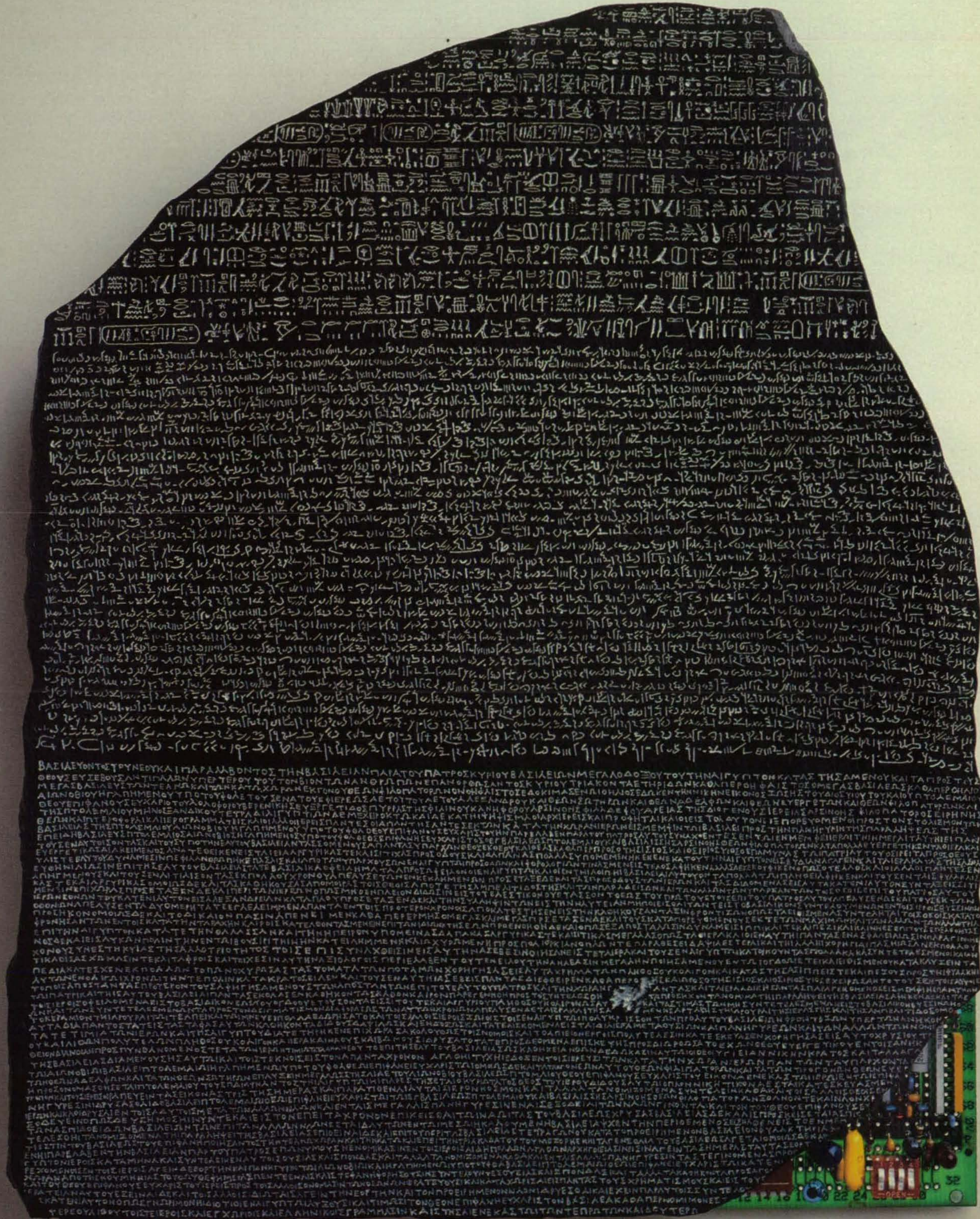
For the Hubble Space Telescope we are providing the Faint Object Spectrograph (FOS), which will see objects up to 15 billion light-years away. Since the universe is estimated to be 18-20 billion years old, astronomers will witness events close to its birth.

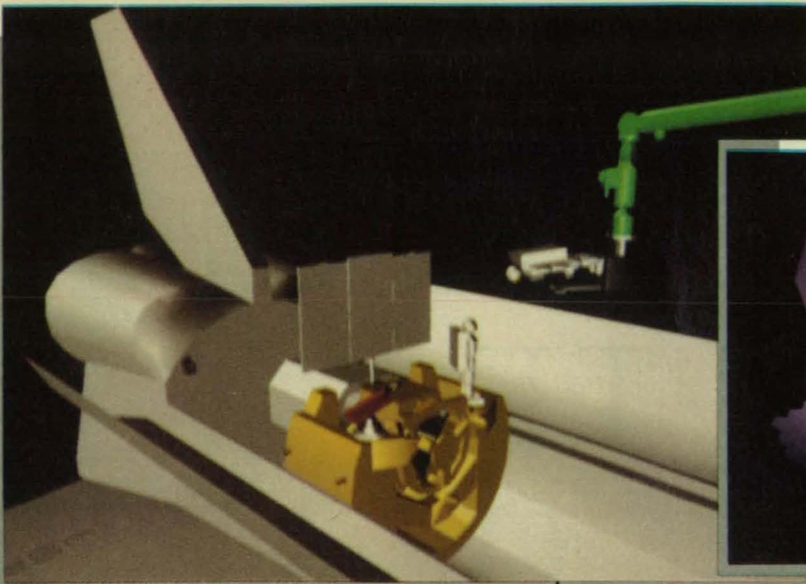


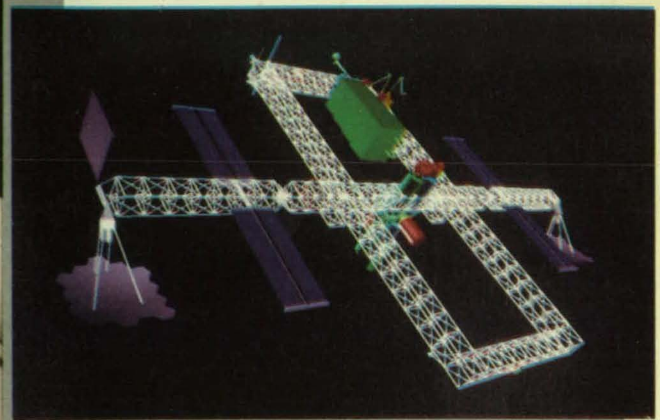
Fine Pointing Simulator

The fine points of fine pointing.

Precisely controlled, space-spanning energy delivery and collection systems create difficult pointing and retargeting challenges, which we can now simulate. This new lab is working toward the precision to zero in on a football-size object 3,000 miles away, in support of the Strategic Defense Initiative research program.







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SPECIAL FEATURES

TECHNICAL SECTION

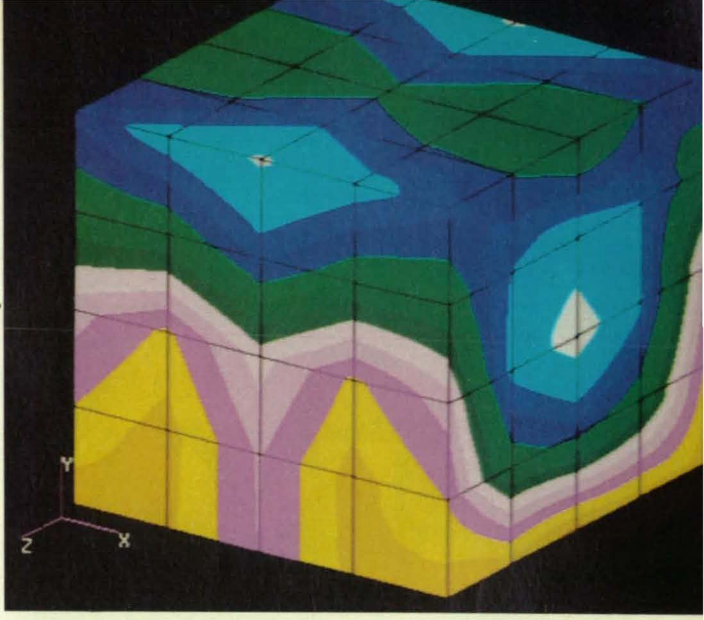
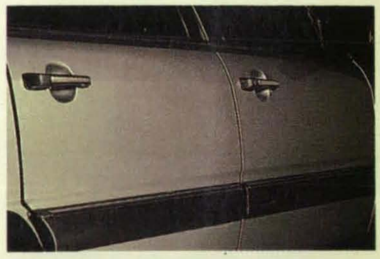


Photo courtesy NASA

Researchers at NASA's Jet Propulsion Laboratory are using the Mark III Hypercube computer to analyze the scattering of electromagnetic waves. The above image shows the magnitudes of the total currents induced on the surface of a perfectly conducting 1.0 x 1.0 x 1.0 meter cube scatterer. ***See page 33.***

DEPARTMENTS

On The Cover: A satellite image of sea surface temperature in the western North Atlantic during June 1984. Warmer hues denote warmer temperatures. NASA is now planning a long-term remote sensing mission called EOS (page 12) to study the oceans, land masses and atmosphere, their interactions, and how the Earth's system is changing. This research holds the key to understanding global warming and other environmental problems. *(Photo courtesy Brown, Evans and Carle, University of Miami Rosenstiel School of Marine and Atmospheric Science)*



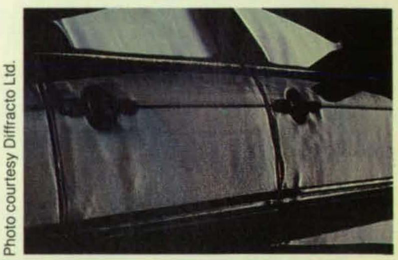


Photo courtesy Diffracto Ltd.

A new machine vision technique called D Sight™ detects and magnifies minute surface flaws. These photos show a car door viewed under normal light (top) and with the D Sight system. ***Turn to page 86.***

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 16). NASA's patent-licensing program to encourage commercial development is described on page 16.

Generating Weighted Test Patterns for VLSI Chips

An Improved built-in self-testing circuit for very-large-scale integrated digital circuits is based on a version of the weighted-test-pattern-generation concept. The approach applied to a commercially-available combinational circuit resulted in 12 weighted test patterns that detected all of the stuck-at-one and stuck-at-zero faults.
(See page 30)

Ballistic-Electron-Emission Microscope

Buried interfaces such as between semiconductor and a thin metal film can be investigated with high spatial resolution by a ballistic-electron-emission microscope that employs scanning tunneling-microscopy methods.
(See page 34)

Isomeric Trisaryloxycyclotriphosphazene Polymer Precursors

The presence of the phosphazene moiety in cyclotriphosphazene-based monomers and polymer precursors is expected to impart special properties in high-performance materials containing inorganic backbones. The substances produced are useful for obtaining heat- and fire-resistant polymers for composites, adhesives, molding powders, and coating laminates.
(See page 42)

Tester Detects Steady-Short or Intermittent-Open Circuits

A simple, portable, lightweight testing circuit sounds a long-duration alarm when it detects a steady short circuit or a momentary open circuit in a coaxial cable or other two-conductor transmission line. The tester is sensitive to discontinuities that last 10 μs or longer.
(See page 18)

Welding-Current Indicator

A simple, inexpensive display circuit indicates when the 3,000-A welding current flows in a welding gun. A light flashes on to indicate high current.
(See page 24)

Articulated Suspension Without Springs

Wheels negotiate bumps and holes with minimal tilting of the vehicle body thanks to a springless suspension. In the new suspension, a wheel can climb an obstacle as high as 1½ times its diameter without excessive tilting of the chassis.
(See page 60)

NASA's Mission To Planet Earth

by Dr. Gerald A. Soffen

A new urgency is driving our need for understanding the Earth and how it works. Humans are no longer mere observers in the events of global change; our industrial and agricultural activities contribute significantly to the Earth's physical condition. During the next century, the current worldwide population of 5.3 billion is expected to grow to 14 billion. Our successful technology will spread across every continent, with vast engineering projects in building roads, clearing forests, and changing waterways. We are no longer surviving in habitable places, we are engineering our planet.

How delicate is our biosphere? Our life support system? We simply do not know. For years we have been aware of our ability to pollute the atmosphere, dump toxic wastes into the water supply, and drive wildlife to extinction. Recently, we have realized that the changes brought on by these activities may be irreversible and may seriously affect our own survival. Scientific conferences have been held to assess the changing Earth and numerous researchers have made predictions about the coming changes. While there is some agreement about the qualitative nature of these changes, there is little agreement about their degree. The difficulty lies in sorting the natural changes from those caused by mankind. We lack a sufficient database to understand the climatic changes on a decade to century scale that are due to forces of nature such as variances in the sun's output, the wobble of the Earth, volcanism, or ocean circulation.

Records revealing the ice ages, crustal plate movements, and past concentrations of trace gases in the atmosphere help put into context the changes we are considering today, but the more subtle changes — a 2° to 6°C rise in global temperature, 50 percent depletion of ozone over Antarctica, or loss of large wooded regions due to acid rain — require more refined measurements over a long, continuous period in order to determine the predictive consequences.

These grave global phenomena have attracted worldwide attention, not only by climatologists but also by social scientists, politicians, and economists. A global warming of 4° C would alter the lives of most of the Earth's inhabitants. Due to the secondary effects of evaporation over the land and oceans and evapotranspiration above the rain forests, the cloud patterns, rain, and snow in the hydrological cycle would be affected. Some areas would be hotter and possibly drier, others wetter or colder.

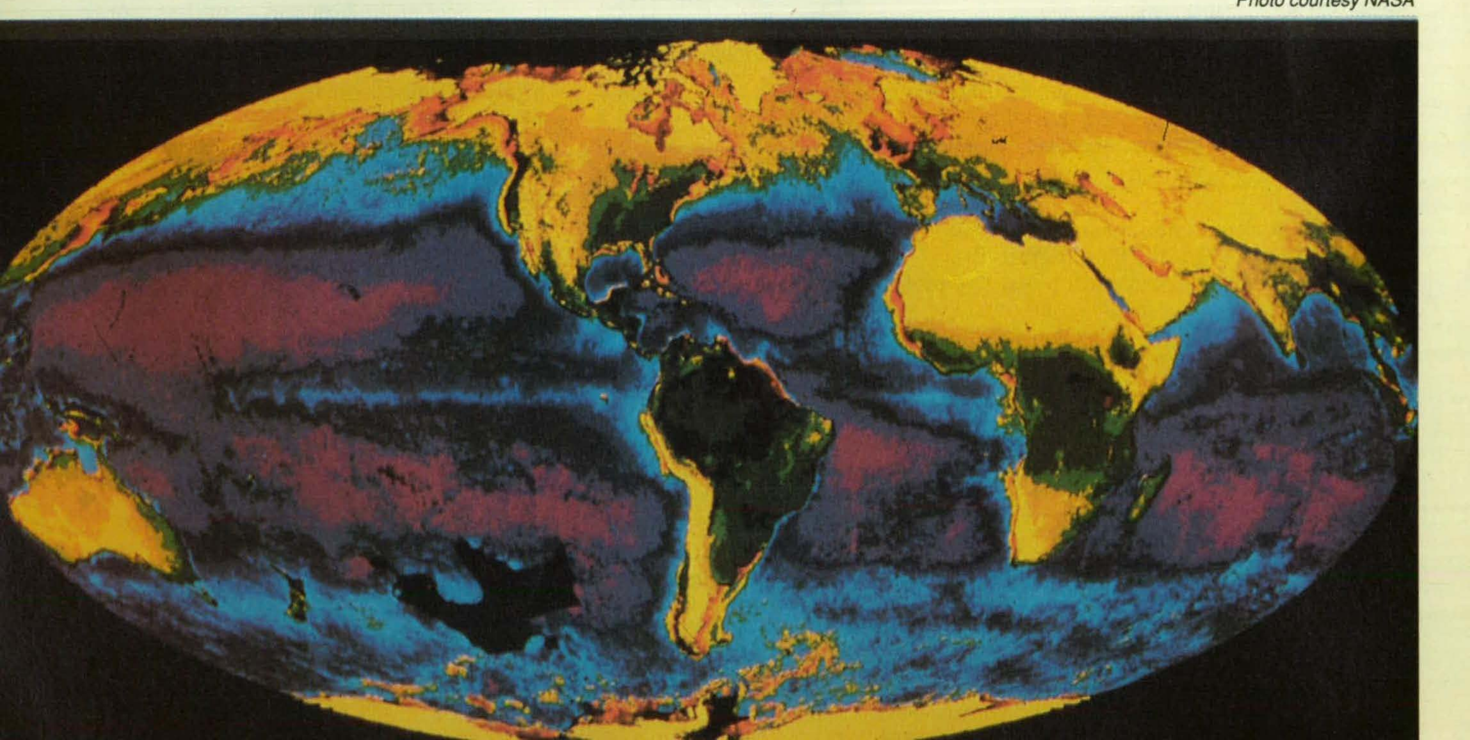
The annual depletion of ozone over the poles has alarmed world health organizations. Ozone in the stratosphere is a shield against the sun's harmful ultraviolet rays. The penetration of this radiation is likely to have a dire effect on both the humans who are exposed and the flora and fauna who cannot take steps to cope with the new environment. Many scientists believe the ozone depletion is caused by traces of chlorofluorocarbon gas released into the atmosphere, and their concomitant chemical interaction.

Acid rain is another result of atmospheric contamination. In this case the air is cleansed by rain, but the resulting acidified sulfur and nitrogen compounds damage the soil and trees. Vast wooded areas have disappeared in recent years and much larger regions of the Earth are believed to be vulnerable.

Perhaps the most serious irreversible change caused by humans is in the Earth's biodiversity. The genetic pool is the result of four-and-a-half billion years of natural selection and evolution. The world's biological state is the net result of changes of nature prescribed by both chance and biological order. Now humans are removing large tracts of forests for industry, and hunting and fish-

The first truly global view of the Earth's biosphere, combining years of data from the Nimbus 7 and NOAA 7 spacecraft, shows Earth teeming with life on both land and sea. Rain forests and other highly productive biological areas appear as dark green, deserts yellow. The concentration of photoplankton, a primary indicator of ocean productivity, is represented by a scale that runs from red (highest) to orange, yellow, green, blue, and purple (lowest).

Photo courtesy NASA



ing with technological efficiency that can destroy a species without intent. One problematic aspect of this is that we have no way of assessing the degree of biological damage. We do not know how many species of life exist on the planet. Some biologists believe there are ten million, others say there are 50 million. We do not understand if we are destroying important species or just perturbing nature slightly.

These and other global problems have forced world leaders to organize international studies. The Earth is now viewed as a system composed of various elements. Scientists who previously specialized in a single field such as oceanography or atmospheric dynamics now realize the importance of interdisciplinary studies. Understanding global warming and other environmental problems will require new interactions among scientists, as well as more data, long-term observations, and advances in sensor and computation technologies.

NASA's Role

NASA has an important role to play and several things to offer. The agency has a powerful research effort in the Earth Sciences and has flown many scientific observatories. It has the world's most advanced civilian program in instrument development and the computational power to support today's best models.

NASA's Earth Sciences program is called Mission To Planet Earth. It has several components: a ground segment using laboratories, balloons, aircraft, field operations, and theoretical studies; spacecraft such as payloads attached to the shuttle or space station Freedom; geostationary platforms; and large polar platforms.

The Earth Observing System (EOS) is a scientific mission using polar-orbiting platforms slated for operation in the late 1990s and into the early part of the next century. The goal is to advance knowledge of the Earth system on a global scale by developing a deeper understanding of the parts of the system, the interaction among them, and how the system is changing. The EOS mission will create an integrated observing system which will enable multidisciplinary study of the Earth's atmosphere, oceans, land surface, polar regions, and biosphere.

The key science areas are the hydrological cycle, the biogeochemical cycles, and the climatological and geophysical processes. Scientists hope to quantify the processes of precipitation, evaporation, evapotranspiration, and runoff on a global basis, and to understand the biogeochemical cycling of carbon, nitrogen, phosphorus, sulphur, and trace metals. Further, they want to assess the influence of sea and land ice cover on global climate and determine the coupling between the lower and upper atmosphere. These are but a few of the many scientific questions now being formulated. The measurements needed to answer them will be made by a variety of instruments, many of which are now under development.

Current plans call for five EOS spacecraft: two from the United States, two from the European Space Agency (ESA), and one from Japan. Other partners include the National Oceanic and Atmospheric Administration (NOAA) and Canada. The NASA spacecraft will be carried into orbit by a Titan IV launch vehicle in late 1997. They will be in sun-synchronous orbits at 705 km altitude with a 1:30 p.m. equator crossing time in the ascending node. The ESA's Columbus spacecraft will be launched on the Ariane and will be sun-synchronous at an altitude of 700 to 850 km with equatorial crossing times of 0930-1030 (descending) and 1330-1430 (ascending).

Instruments will be shared among the partners, and in some cases one agency's instrument may be launched on another's spacecraft. The agreement calls for all of the data to be available to any qualified research scientist. This "open data" policy is vital to the success of EOS.

The strategy of combining measurements and observations from the various platforms requires an elaborate plan for covering the Earth. For certain measurements the direction of pointing or field of view is critical. In some cases observations of the same region must be made by several spacecraft simultaneously, while in other cases the time of day or changing season is important. Each class of instrument has a particular set of requirements and this has to be worked into a pattern that will optimize the combined results of all the missions.

From the position of a satellite looking down on the Earth, a main consideration of what can be measured is the transmission of the various wavelengths of the electromagnetic spectrum through the Earth's atmosphere, which is opaque to most of the spectrum. This opacity is due mainly to molecular, aerosol, or water absorption. Radiation breaks through in the optical region, certain bands in the infrared (IR), and in the microwave region beyond 0.1 cm wavelength. Hence, EOS instruments will operate selectively in two bands: the optical-IR and the microwave.

Instruments NASA is considering for its polar-orbiting platforms include:

MODIS — moderate-resolution imaging spectrometer for surface and cloud imaging in the visible and infrared 0.4-2.2 nm, 3-5 µm, 6-14 µm resolution ranging from 10 nm to 0.5 µm. Two of these are planned, one pointed in the nadir to look at the land surface, and the other in a tilt mode to observe the ocean at different sun glint angles.

This artist's concept highlights the science instruments of an EOS polar-orbiting platform.

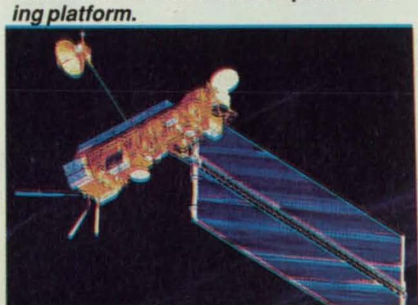


Illustration courtesy NASA

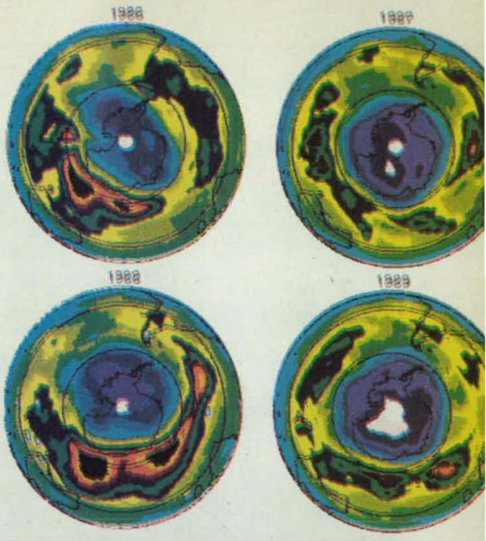


Photo courtesy NASA

These Southern Hemisphere plots illustrate the total ozone distribution for September 22 over the last four years. They show that the areas of lowest ozone (purple shades) in 1986 and 1988 covered significantly less area than the ozone holes observed in 1987 and 1989, which covered nearly the entire Antarctic continent. The Total Ozone Mapping Spectrometer (TOMS) instrument on NASA's Nimbus 7 satellite captured this data.

HIRIS — high-resolution imaging spectrometer for surface imaging 0.4-2.2 nm, 10-20 nm spectral resolution. This instrument will use 192 channels to obtain detailed 30m resolution maps of selected areas of the Earth. Volcanologists, geochemists, and biologists are particularly interested.

AIRS-AMSU — atmospheric infrared sounder will observe atmospheric temperature profiles and other properties. Its field of view is 15-50 km.

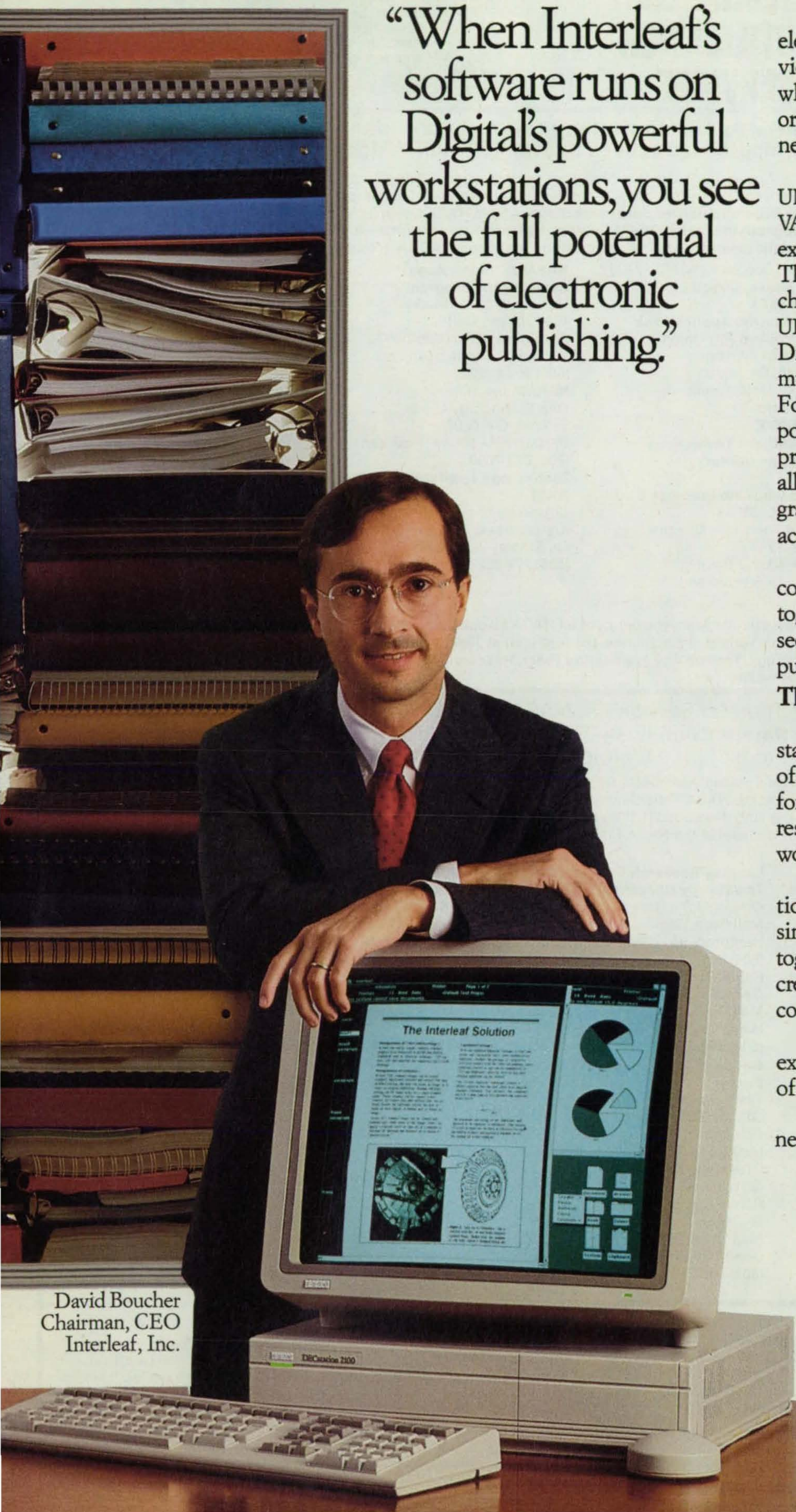
CERES (clouds and the Earth's radiant energy) — Based on the ERBE scanners, CERES will measure radiation at the top of the atmosphere and at the Earth's surface. It will provide data on cloud coverage, altitude, condensed water density, and optical depth.

HIMSS — high-resolution microwave spectrometer sounder will feature a rotating 2m parabolic antenna operating at 90-6.6 GHz which will measure precipitation, sea surface temperature, and snow cover depth.

TES — tropospheric emission spectrometer is a high-spectral-resolution infrared Fourier transform spectrometer that will enable researchers to monitor many of the minor constituents of the lower atmosphere.

The nucleus of EOS is the Data and Information System and the scientists who will handle the data. EOS data will be transmitted by the Tracking and Data Relay Satellite System and distributed around the world to thousands of scien-

(continued on page 81)



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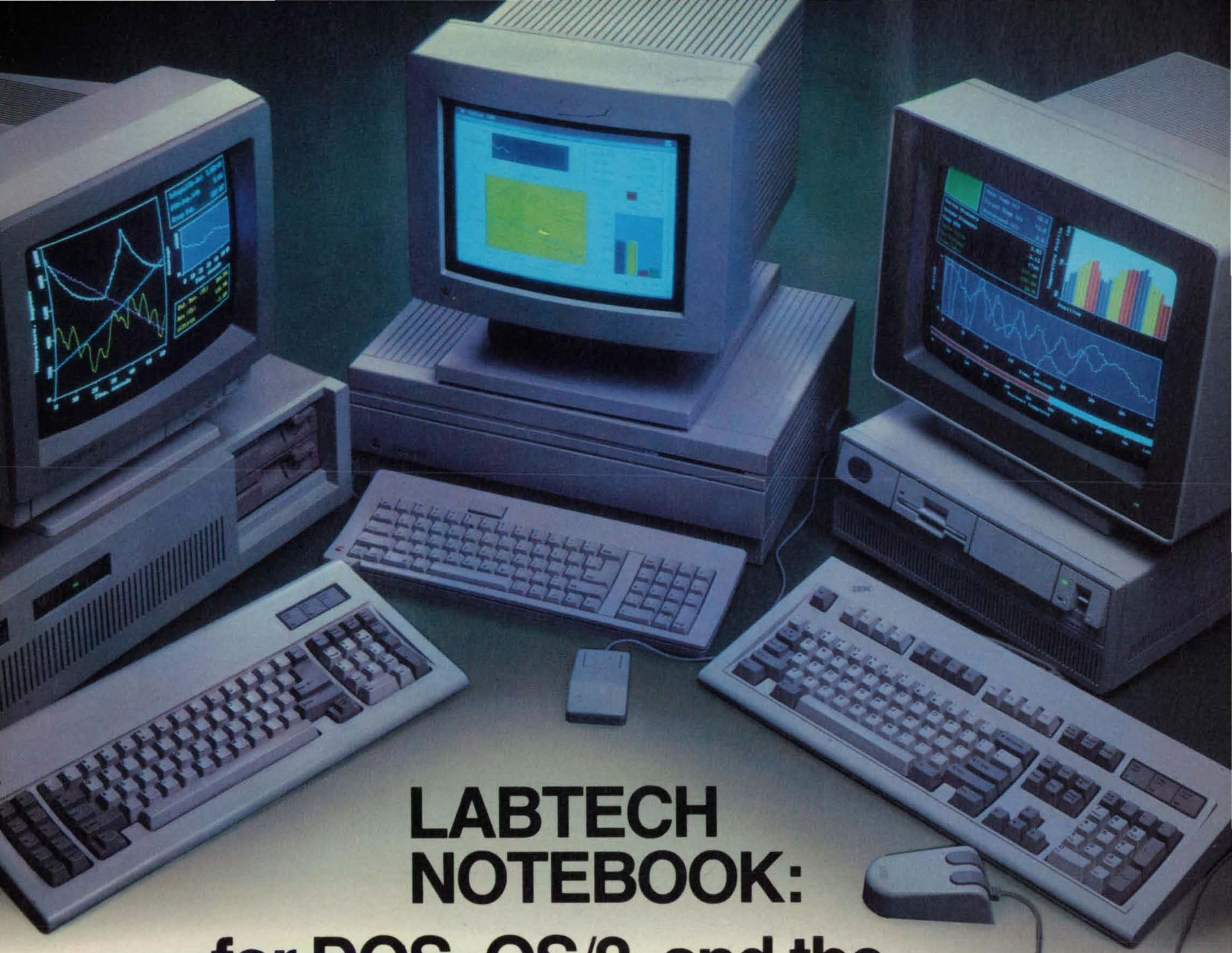

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Circle Reader Action No. 423

Tester Detects Steady-Short or Intermittent-Open Circuits

Momentary open circuits or steady short circuits trigger a buzzer.

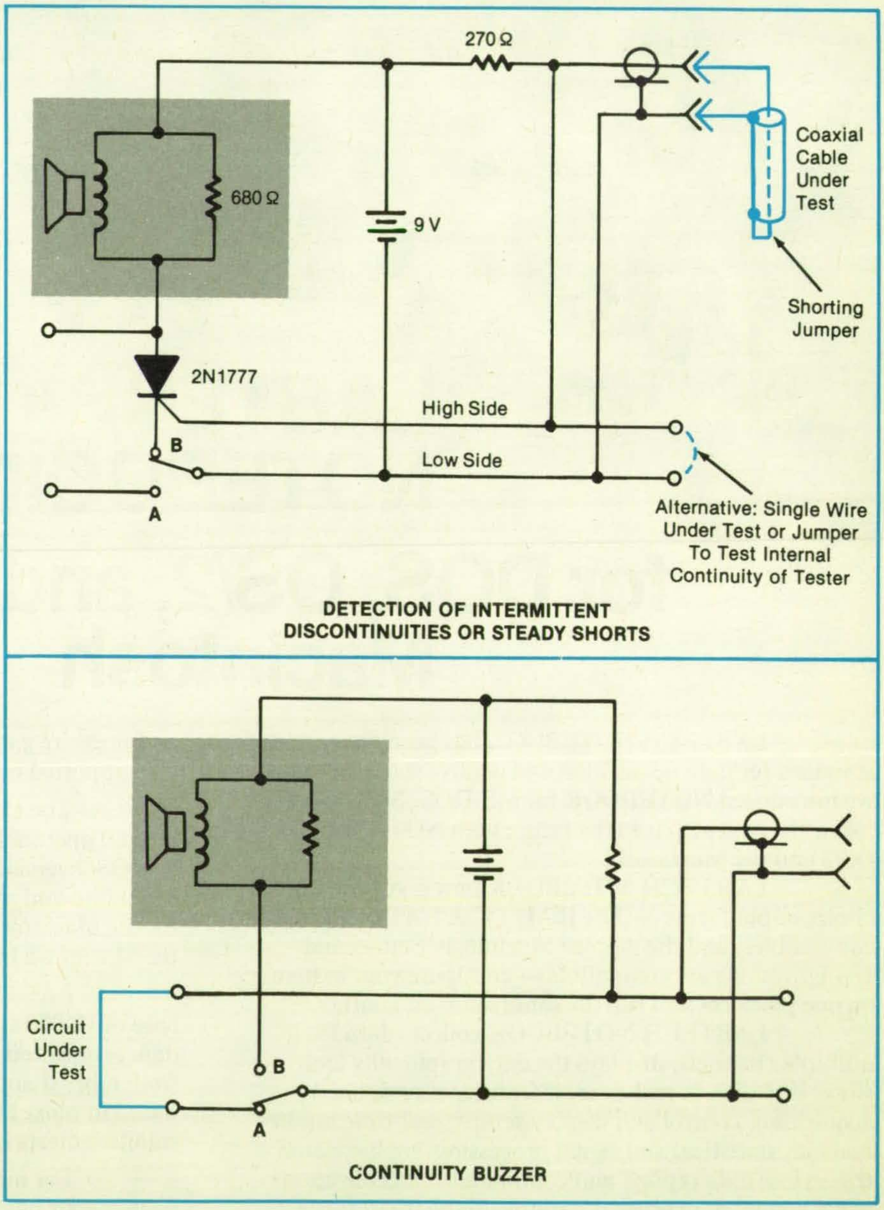
Marshall Space Flight Center, Alabama

A simple, portable, lightweight testing circuit sounds a long-duration alarm when it detects a steady short circuit or a momentary open circuit in a coaxial cable or other two-conductor transmission line. The tester is sensitive to discontinuities that last 10 μs or longer. Previously, there was no simple, portable instrument to detect momentary shorts or discontinuities. Such conventional instruments as ohmmeters and lamp- or buzzer-type continuity checkers give visible or audible indications of steady open or closed circuits only.

To detect an intermittent open circuit in a coaxial cable, the far end of the cable is shorted by a jumper, and the tester is connected as shown in the upper portion of the figure, with the switch in position B. If the cable is in good condition, the high-side terminal remains grounded, the silicon controlled rectifier remains off, and the buzzer does not sound. If an opening occurs in the center conductor or shield of the coaxial cable, the current from the high-side terminal to the low-side terminal that would otherwise be shunted by the cable flows into and triggers the silicon controlled rectifier and thereby turns on the buzzer. Even if the coaxial cable starts to conduct again, the buzzer remains on until the silicon controlled rectifier is reset by turning the switch to position A. An intermittent discontinuity in a single wire (or an internal discontinuity in the tester) can be detected in this manner if no coaxial cable is connected and the wire or jumper is connected as shown in dashed lines.

To detect a steady short circuit, the jumper is removed. If the buzzer does not sound, there is a steady short circuit between the inner and outer conductors. If the buzzer does sound, then the cable is either good or open.

The tester is used extensively for detecting intermittent open shorts in accelerometer and extensometer cables. The tester can also be used as an ordinary buzzer-type continuity checker to detect steady short or open circuits. For this purpose, the switch is set at position A and the probe leads are connected as shown by dashed lines in the lower portion of the figure. In this case, the silicon controlled rectifier is not part of the circuit, and the buzzer remains on only so long as the circuit under test provides a conducting path.



The **Tester Detects Intermittent Discontinuities** (above) or shorts (below, right connections). It can also be used as an ordinary continuity buzzer (below, left connections).

This work was done by Bobby L. Anderson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29466

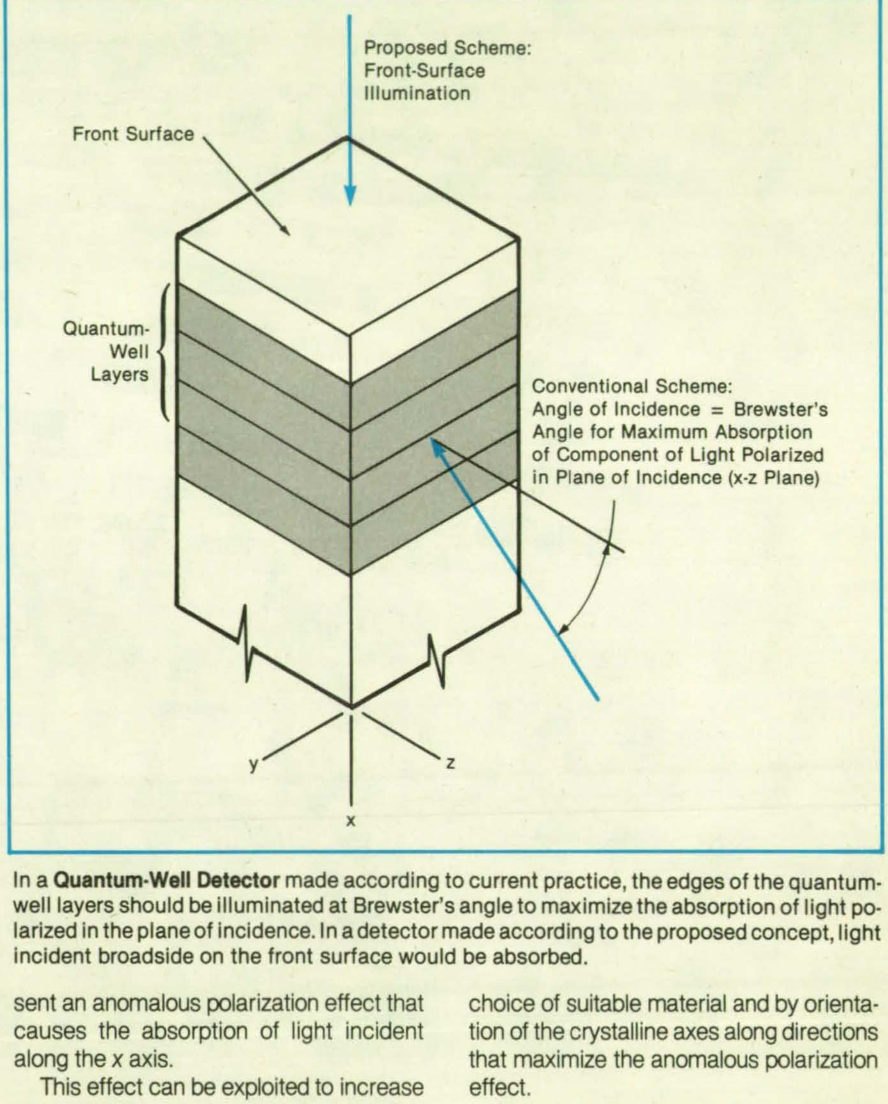
Anomalous Polarization May Improve Infrared Detectors

New configurations are proposed for quantum-well devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

An anisotropic quantum effect that has been overlooked until now may simplify the alignment, increase the sensitivity, and open up more possibilities in the design of quantum-well detectors of infrared radiation. Heretofore, it has been thought necessary to illuminate such a device at Brewster's angle (see figure) to maximize the absorption of light by channeling, into the waveguide structures defined by the quantum-well planes, as much as possible of the component of incident radiation that is polarized perpendicularly to these planes. However, a device made according to the newer concept could be illuminated directly on its front side; no special waveguide structures would be required.

The behavior of a quantum-well device can be analyzed via the effective-mass approximation. Such an analysis shows that if the device material has an isotropic effective mass, then the component of incident radiation polarized in the quantum-well plane (*y-z* plane) does not induce a transition of an electron between different subband energy states; that is, the transition is quantum-mechanically forbidden. Thus, radiation incident along the *x* axis or otherwise polarized in the *y-z* plane is not absorbed and no photocurrent is generated. To effect a transition in the isotropic device, the radiation must have a component polarized along the *x* axis, and this gives rise to the need for the Brewster's-angle/waveguide scheme.



In a **Quantum-Well Detector** made according to current practice, the edges of the quantum-well layers should be illuminated at Brewster's angle to maximize the absorption of light polarized in the plane of incidence. In a detector made according to the proposed concept, light incident broadside on the front surface would be absorbed.

The planes of the quantum wells are perpendicular to the direction of growth (*x* axis). The quantum theory shows that if the material has an anisotropic effective-mass tensor and if the direction of growth is not a principal crystalline axis of the device material, then nonzero off-diagonal (*xy* and *yz*) matrix elements arise between subband energy states, even when the light is incident along the *x* axis (polarized in the *x-z* plane). These matrix elements represent an anomalous polarization effect that causes the absorption of light incident along the *x* axis.

This effect can be exploited to increase the sensitivity of an infrared detector by illuminating the front surface broadside (light incident along the *x* axis) to take advantage of its large surface area, which can be of the order of 1 cm^2. The sensitivity of a device could be maximized by the choice of suitable material and by orientation of the crystalline axes along directions that maximize the anomalous polarization effect.

This work was done by Chan-Lon Yang of Caltech and Dee-Son Pan of UCLA for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 113 on the TSP Request Card.*
NPO-17450

Calculating Second-Order Effects in MOSFET's

These effects become important as dimensions shrink to a micron.

NASA's Jet Propulsion Laboratory, Pasadena, California

A collection of mathematical models includes second-order effects in n-channel, enhancement-mode, metal-oxide-semiconductor field-effect transistors (MOSFET's). When dimensions of circuit elements were relatively large, these effects could be neglected safely. However, as the very-large-scale integration of microelectronic circuits leads to MOSFET's shorter or narrower than 2 μm, these effects become significant in design and operation. Such computer programs as the widely-used "Simulation Program With Integrated Circuit Emphasis, Version 2" (SPICE 2) include many of these effects.

The first-order equations for the threshold voltage and drain current are derived from basic equations of electrostatics and the physics of semiconductors, with simplifying assumptions regarding the distributions of charges, currents, and electrostatic potentials. The second-order equations, which provide partial corrections for these

assumptions, are grouped into four categories.

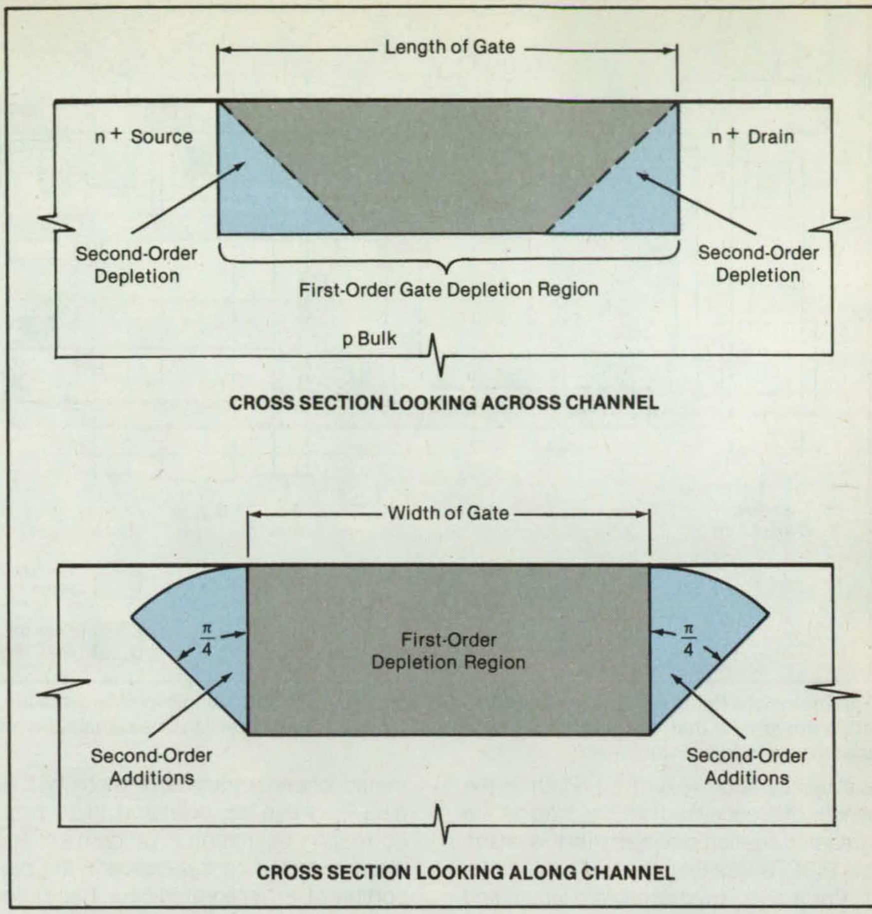
One category includes equations for the effects of shortness and narrowness of the channel on the threshold voltage. The second-order equation for the short-channel effect is derived by representing the side-view cross section of the gate-depletion region as a trapezium or trapezoid, to account for the encroachment of the junction-depletion regions on the rectangular gate-depletion region of the first-order model. The second-order equation of the narrow-channel effect accounts for the fact that the gate depletion includes an approximately-wedge-shaped bulge beyond the sides of the metal gate (see figure). This category also includes the static feedback effect, alternatively called drain-induced barrier lowering, which accounts for the effect of the drain-to-source voltage on the threshold voltage.

The next category involves equations for the drain-to-source current. The effects of shortness, narrowness, and drain-induced barrier lowering are taken into account to obtain a more precise equation for the drain current. Of particular interest are the equations for saturation and subthreshold (leakage) drain currents. This category also includes an equation for the shortening of the effective channel length that occurs when the drain-to-source voltage exceeds the saturation value.

The models of the third category account for the decrease of the drift mobility of electrons at the surface of the channel. Such quantities as the drain current and the propagation delay depend strongly on the mobility. Transverse electric fields affect the mobility by driving electrons into the Si/SiO_2 interface, while longitudinal electric fields affect mobility via the drift velocity. The effect of both fields combined can be expressed in a single equation as a function of the drain-to-source voltage.

The last category includes equations for capacitance and the conservation of electric charge. For this purpose a MOSFET is represented by an assembly of capacitors with appropriate series and parallel connections. Equations for the input capacitance under saturated and unsaturated conditions are derived from the basic equations for the gate/source- and gate/drain-depletion capacitances.

This work was done by Reuben Benumof, John A. Zoutendyk, and James R. Coss of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 31 on the TSP Request Card.*
NPO-17395



In the **Second-Order Models** of an n-channel, enhancement-mode MOSFET, the first-order gate-depletion region is diminished by triangular-cross-section deletions on the end and augmented by circular-wedge-cross-section bulges on the sides.

Asymmetric Memory Circuit Would Resist Soft Errors

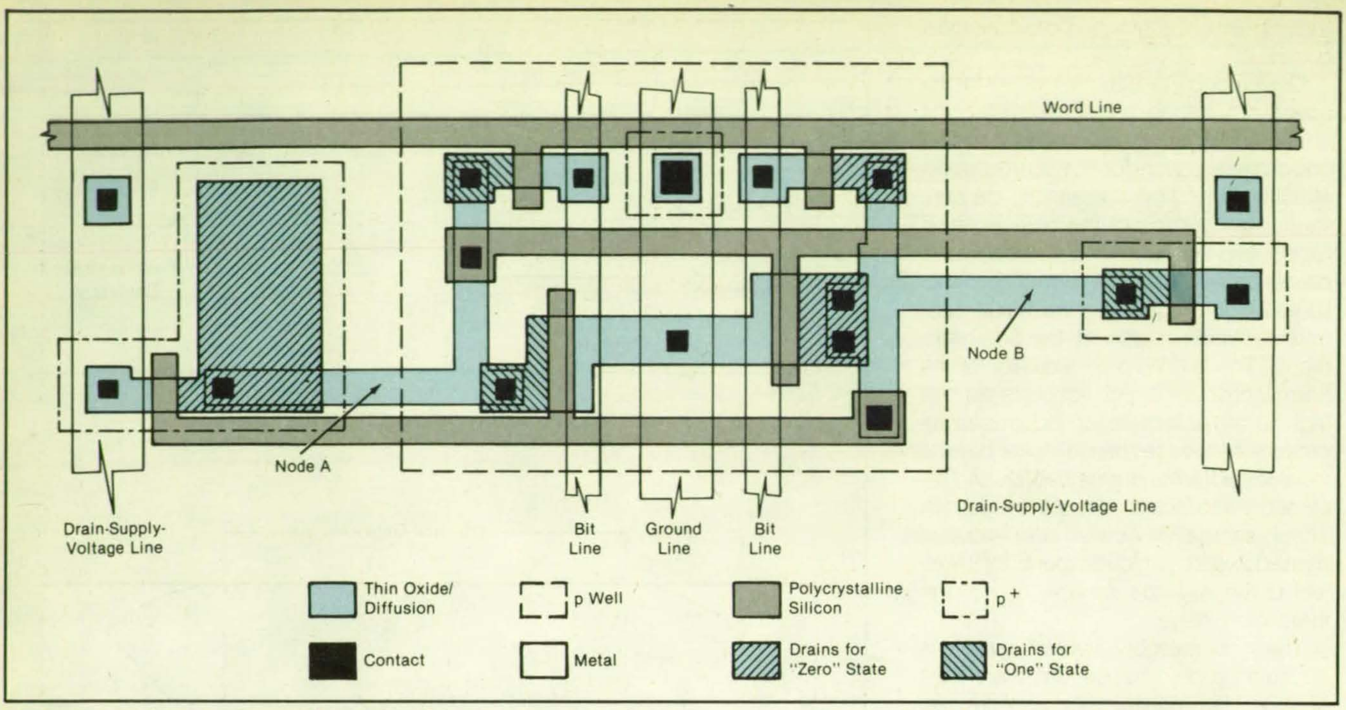
Some nonlinear error-correcting codes are more efficient in the presence of asymmetry.

NASA's Jet Propulsion Laboratory, Pasadena, California

A combination of circuit-design and coding concepts is expected to make integrated-circuit random-access memories more resistant to "soft" errors (temporary bit errors, also called "single-event upsets" due to ionizing radiation). An integrated circuit of the new type would be made deliberately more susceptible to one kind of bit error than to the other, and the associated error-correcting code would be adapted to exploit this asymmetry in error probabilities.

A random-access memory can be regarded as a communication channel with a long delay, in which the writing and reading operations correspond to transmitting and receiving, respectively. In a binary symmetric communication channel, the probability of an erroneous transition from 0 to 1 equals the probability of an erroneous transition from 1 to 0. Linear error-correcting codes for binary symmetric channels are well developed; such codes can be applied to data written into symmetric random-access memories, and decoding and error correction can take place during the subsequent reading operation. The error-correcting capability of such a code increases with the apportionment of more bits within fixed-length code words as parity-check bits. Thus, as the error-correcting ability increases, less information can be stored and retrieved, and vice versa.

In a random-access-memory cell, the probability P(01) or P(10) of an erroneous zero-to-one or one-to-zero transition, respectively, can be increased by enlarging those circuit elements that are more susceptible to one of these types of error (see figure). Nonlinear group-theoretical error-correcting codes can be adapted to exploit the asymmetry of an ideal binary asymmetric channel, in which only one kind of erroneous transition occurs [e.g., P(10) = 0]. In practice, it is not necessary to have an ideal binary asymmetric channel as long as the ratio of transition probabilities is



The **Drains of a Random-Access-Memory Cell** that are susceptible to single-event upsets are indicated by crosshatching. Those for the "zero" state are greater than those for the "one" state. Thus, erroneous zero-to-one transitions are more probable than are erroneous one-to-zero transitions in this circuit.

sufficiently large [e.g., $P(01)/P(10) >$ the length of a codeword] and as long as the greater transition probability [in this example $P(01)$] is less than one-half.

For a given fixed codeword length and error-correcting capability, the number of distinct code words in a group-theoretical code for a binary asymmetric channel often exceeds the number of code words in a code for a binary symmetric channel. Equivalently, for the same codeword length and error-correcting ability, a binary asymmetric channel can carry more bits of data — or use less overhead. In an error-correcting asymmetric random-access memory based on this concept, the proportion of an integrated-circuit chip devoted to the correction of errors can thus be made smaller than in a symmetric version. Alternatively, for the same error-correcting proportion, the error-correcting capability of the asymmetric version can be greater.

This work was done by Martin G. Buehler and Marvin Perlman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 130 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17394.

Welding-Current Indicator

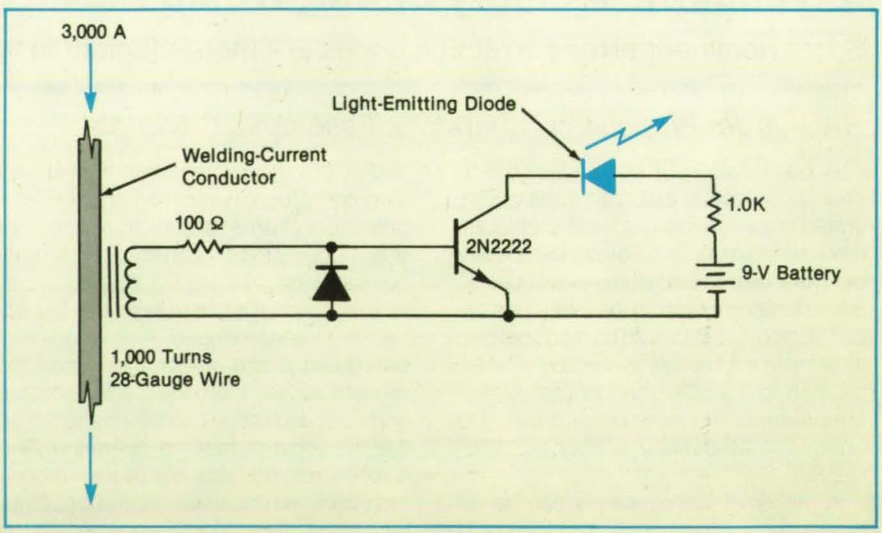
A light flashes on to indicate high current.

Marshall Space Flight Center, Alabama

A simple, inexpensive display circuit indicates when the 3,000-A welding current flows in a welding gun. The onset of the welding current induces a voltage and current in a 1,000-turn, 28-gauge copper-wire coil (see figure). A single-transistor amplifier amplifies the induced current, energizing a light-emitting diode (LED) connected to the collector of the transistor. Light from the LED thus gives a simple, direct indication of the welding current.

The battery-powered circuit is a low-cost, straightforward alternative to a current probe, which would require an oscilloscope to indicate that the gun is on or off. The operator would have to divide attention between the oscilloscope and the gun.

This work was done by Milton C. Hensley, Steven W. Huston, and Ralph E. Kroy of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29574*



This **Simple One-Transistor Circuit** turns on a light to indicate that a 3,000-A welding current is flowing.

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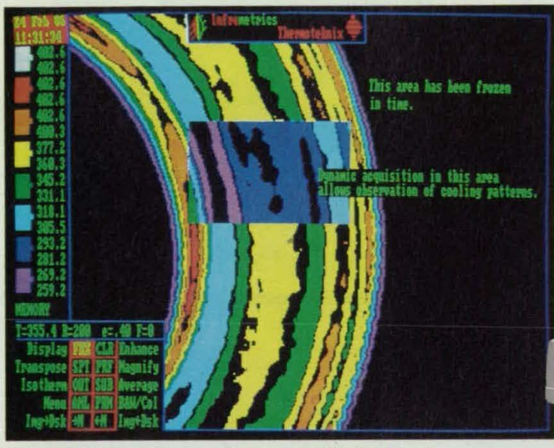

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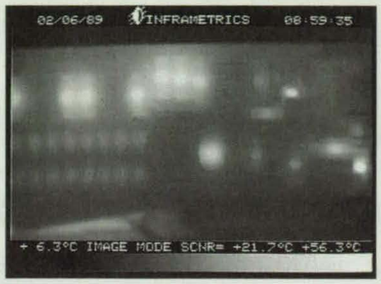

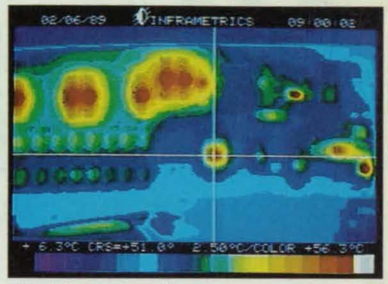

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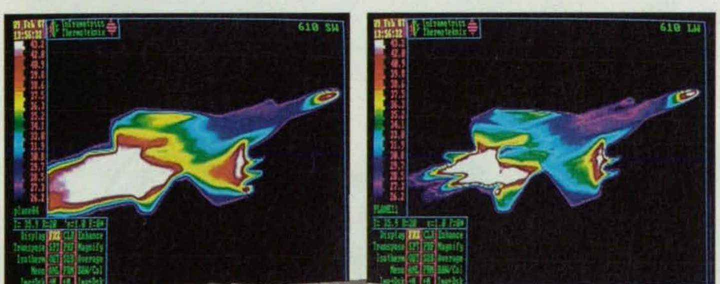


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Circle Reader Action No. 370

Electronic Systems

Camera Would Monitor Weld-Pool Contours

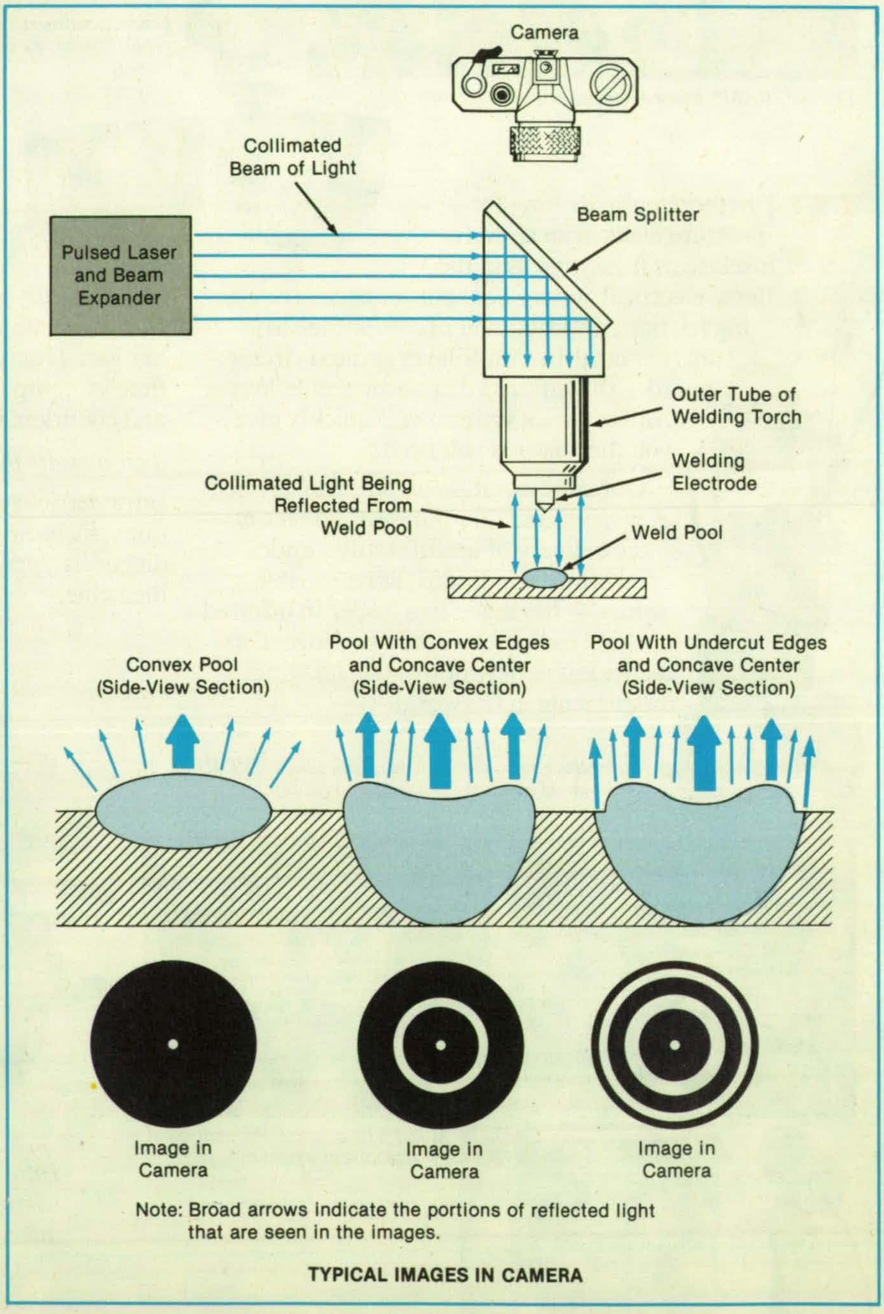
The weld pool would be illuminated and viewed coaxially along the welding torch.

Marshall Space Flight Center, Alabama

A proposed monitoring subsystem for an arc welder would provide an image in which the horizontal portions of the surface of the weld pool are highlighted. The proposed subsystem differs from two other developmental contour-monitoring subsystems, one of which measures the angle of reflected light to analyze the contour at one point at a time and the other of which uses reflections of light at various angles from an array of point sources. In the proposed subsystem, the weld pool would be illuminated and viewed along the axis of the welding torch. This configuration would ease somewhat the interpretation of the image data and would confine the viewing optics to a small package close to the weld, enabling use in applications in which visual access would otherwise be restricted.

A collimated beam of light from a pulsed laser would strike a beam splitter, which would reflect the beam down along the axis of the torch onto the weld pool (see figure). Where the surface of the pool is horizontal or nearly so, it would reflect some of the light back through the beam splitter to a video camera. Thus, the horizontal or nearly horizontal parts of the surface of the weld pool would appear bright in the image. Because little light from the other parts of the surface would reach the camera, those parts would appear dark. The positions of the camera and the laser can be interchanged from those shown in the figure, provided that the thick beam splitter is replaced by a pellicle beam splitter or coated on one surface to eliminate spurious reflections.

The lower part of the figure gives examples of images representative of three typical weld-pool surfaces. The number, sizes, positions, and relative movements of the bright rings could be processed by an image-analyzing subsystem to infer the surface contour of the pool and, thus, the characteristics of the weld. For example, a distinct bright ring as shown in the middle illustration may be a good indication of full penetration of the weld, and the diameter



The **Weld Pool Would Be Illuminated** with pulsed, collimated laser light and viewed along the vertical axis of illumination. Only horizontal and nearly horizontal parts of the surface of the weld pool would appear bright in the image seen by the camera.

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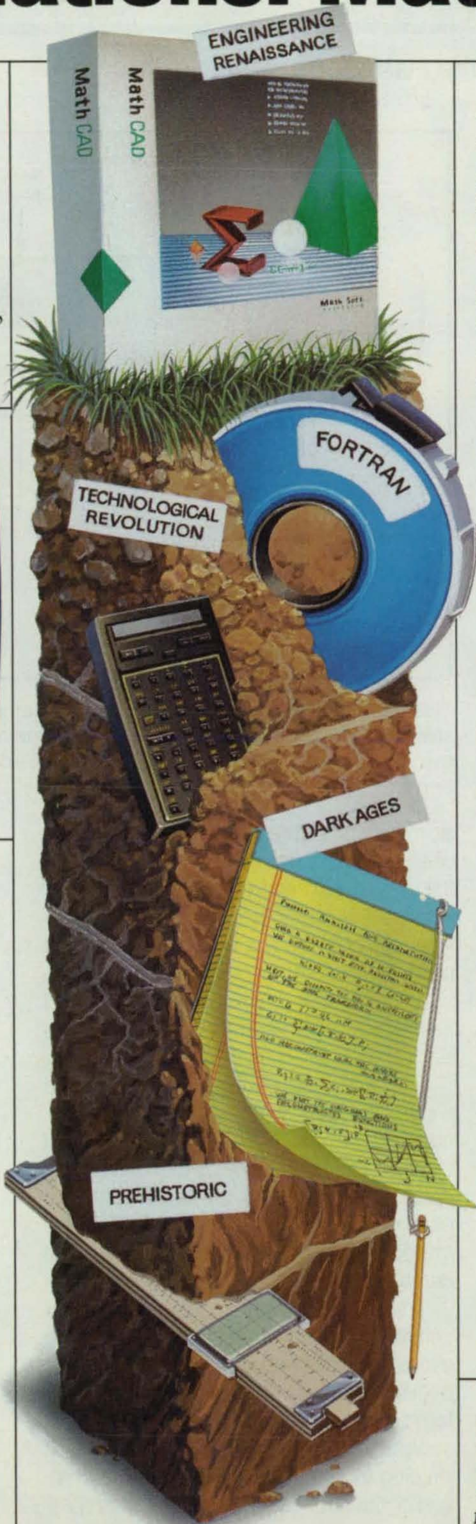

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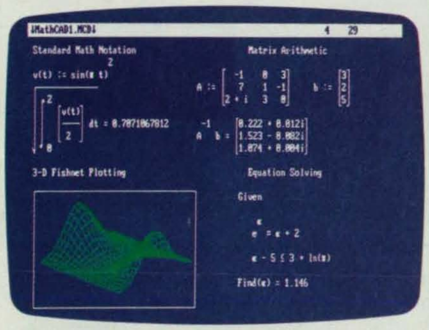

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Circle Reader Action No. 628

of the ring may indicate the width of the back bead.

The monitoring and analyzing subsystems could be integrated into the overall control system of a robotic welder. The control system would set the welding parameters (current, vertical position, speed, and the like) to adapt to changing conditions, maintaining the surface contour that gives the desired pattern of reflections. This function could be combined with the developmental through-the-torch seam-tracking function, which can derive feedback signals from the same coaxial view.

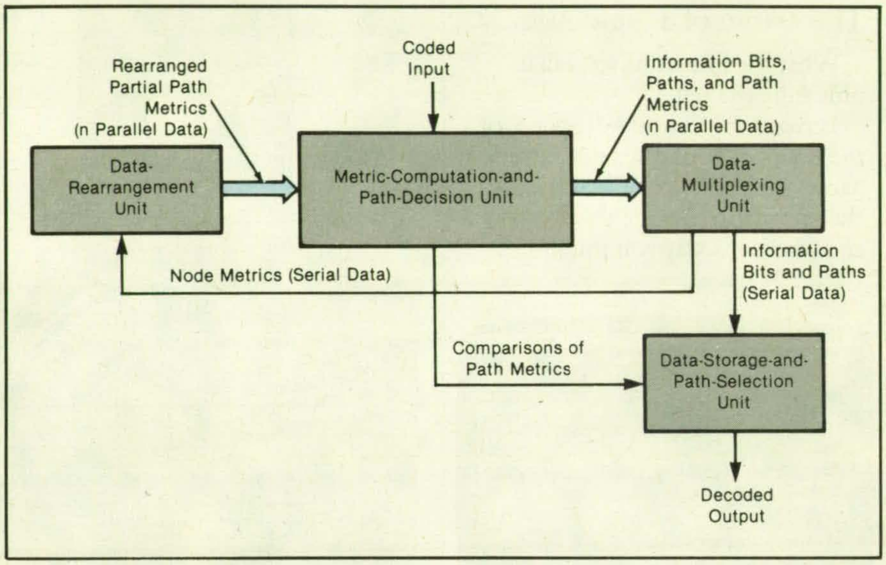
This work was done by Stephen S. Gordon and David A. Gutow of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29450

VLSI Architecture for Viterbi Decoder

Circuits of reasonable size can process convolutional codes of large constraint lengths.

NASA's Jet Propulsion Laboratory, Pasadena, California

A "pipeline" architecture has been developed for very-large-scale integrated (VLSI) Viterbi decoding circuits for binary convolutional codes of large constraint lengths. In this scheme, a single sequential processor computes the path metrics in the trellis diagram (the diagram in which the paths and nodes represent the possible sequences of code states and in which the metrics indicate the relative likelihoods of the sequences). The systolic-array method is used to store the path information as well as to choose the path with the best metric.



This **VLSI Viterbi-Decoder Architecture** is a compromise between speed and complexity. The size of the decoding circuit increases approximately linearly with the constraint length of the code, and additional circuit chips can be added with moderate numbers of interconnections.

The basic Viterbi decoding algorithm processes the received message in an iterative manner. At each step, it compares the metrics of all paths entering each decoder state and stores the path with the largest metric (the "survivor" path), along with its metric. The number of possible decoder states and, consequently, the complexity of a conventional decoding circuit increase exponentially with K, the constraint length of the code. For example, with $K = 14$, the number of states is $2^{K-1} = 2^{13} = 8{,}192$: This is too large for implementation on a single VLSI circuit chip, and heretofore, the practical limitation on the number of input/output pins on a chip has made it difficult to partition a decoder into multiple chips.

The new decoder architecture executes a modified Viterbi algorithm in which the path memory of the decoder is truncated and the message is, in effect, decoded in pieces $5K$ long, rather than as a whole. The decoding functions are performed by a data-rearrangement unit, a metric-computation-and-path-decision unit, a data-multiplexing unit, and a data-storage-and-path-selection unit (see figure).

The data-rearrangement unit contains shift registers of length 2^{K-2}. This unit changes the sequences and correspondingly rearranges the partial path metrics of data fed back serially from the data-multiplexing unit. The shift-register cycle is n times as fast as the master-clock cycle of the system (where n is the number of code bits needed to transmit 1 uncoded information bit).

The metric-computation-and-path-decision unit computes the new partial metrics of all the paths entering a state by adding the computed branch metrics entering that state to the metric of the connecting survivor at the preceding time unit. The partial path metrics of all paths entering each state are compared, and the survivor and its metrics are selected while other paths and metrics are eliminated.

The data-multiplexing unit changes the n parallel outputs of the metric-computation-and-path-decision unit to sequential order. This can be done by use of a switch operating n times as fast as the master clock so that the two output data from the metric-computation-and-path-decision unit can be sampled adequately.

The data-storage-and-path-selection unit stores both the surviving paths and the estimated information bits. The decoding decision is made after $5K$ periods. The information bits stored in the data-storage subunit are then read out sequentially, yielding the most-likely estimated information contained in the received coded message.

The new decoder architecture is an engineering compromise between complexity and computing speed. In the new architecture, the complexity increases only linearly with K, and consequently a moderate-constraint-length decoder can be built on a single VLSI circuit chip by current fabrication techniques. Where K is too large for a single-chip implementation, the new architecture makes it possible to partition a Viterbi decoder with relative ease into several chips with a moderate number of interconnections.

This work was done by In-Shek Hsu and Trieu-Kie Truong of Caltech and I. S. Reed and J. Sun of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 100 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17310.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Generating Weighted Test Patterns for VLSI Chips

Built-in self-testing circuitry is based on probabilistic fault-detection concepts.

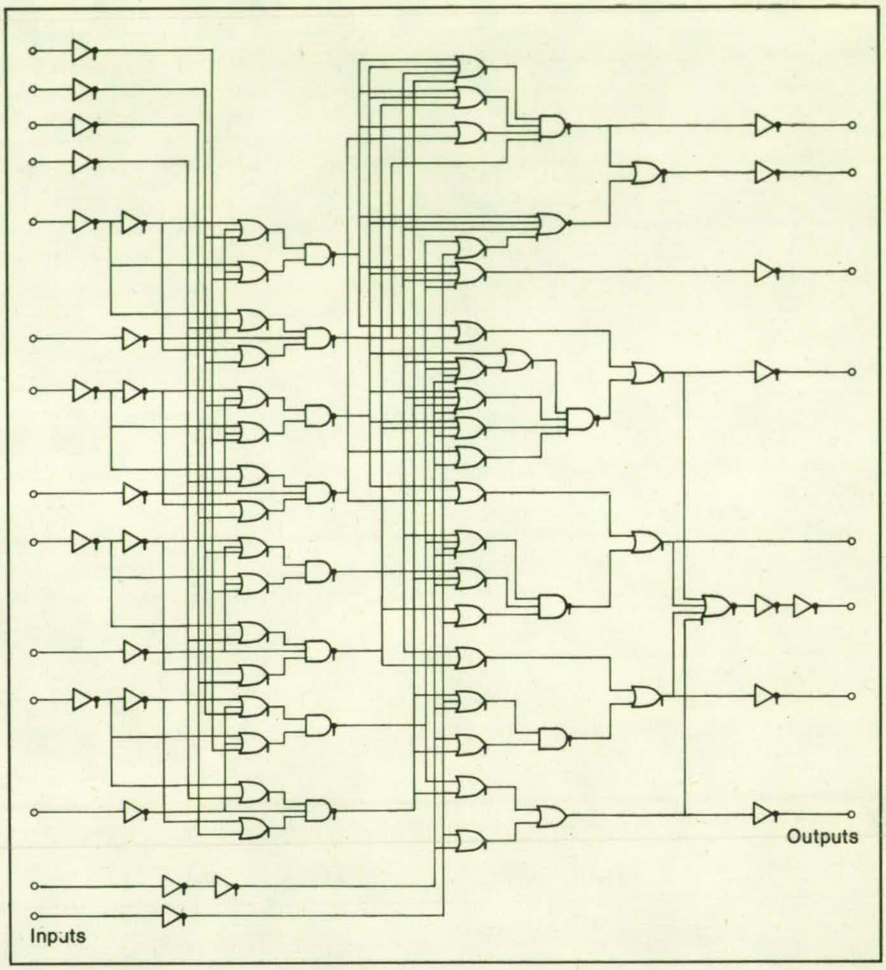
NASA's Jet Propulsion Laboratory, Pasadena, California

Improved built-in self-testing circuitry for very-large-scale integrated (VLSI) digital circuits is based on a version of the weighted-test-pattern-generation concept, in which ones and zeros in pseudorandom test patterns occur with probabilities that are weighted to enhance the detection of certain kinds of faults. In comparison with previous built-in testing circuitry, the improved circuitry requires fewer test patterns and less computation time and occupies less area on circuit chips.

In the new approach, functional test patterns ordinarily used to verify designs are also used to derive the desired weights. Because it is customary to generate such patterns in any event, this involves no additional cost. It is also necessary to simulate the logic of the circuit to be tested to observe the outputs that should occur upon application of each functional test pattern or set of patterns. It is easy to relate the switching activity in the outputs with the fault-detection activity by use of probabilistic fault-detection techniques.

The steps of the new approach are as follows:

1. Generate a set of functional test patterns for the circuit to be tested.
2. Simulate faults in the circuit to be tested, and record the faults that are detectable via changes in the outputs.
3. Count the frequencies of recurrence of ones and zeros.
4. Correlate the number of faults detected with the frequencies determined in step 3.
5. Use the signal probabilities from the preceding steps to weight the pseudorandom patterns generated by the linear-feedback shift register (which is the part of the built-in test circuit that generates the test patterns).
6. Simulate faults to determine whether additional faults can be detected.



This **Four-Bit Arithmetic-and-Logic Unit**, the RCA CD40181 (or equivalent), has been used widely to test test-pattern-generation concepts.

The new approach was applied to a commercially-available combinational circuit (see figure). The result was 12 weighted test patterns that detected all of the stuck-at-one and stuck-at-zero faults.

This work was done by Fardad Siavoshi of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 66 on the TSP Request Card.*
NPO-17514

Portable High-Frequency Data-Acquisition System

A compact unit would be made of readily available solid-state components.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed system for the acquisition of rapidly changing data would be self-contained and portable. The system was conceived for monitoring such aerodynamic effects as flutter, vibration, shock, sound, and pressure. It offers precise and fast acquisition of data and large data-storage capacity: it would have a maximum sampling rate of 125 kHz, an access time of 15 ns, and a 1-million-bit memory.

The system would measure time with a "smart" (microprocessor-controlled) watch that could maintain calendar time for more than 10 years without external power. It would provide standby power from a "smart" battery that could furnish up to 1 ampere-hour of charge if power from the main batteries were lost.

A silicon transducer would send an analog signal representing the dynamic phenomenon being monitored to an integrated analog-to-digital (A/D) package (see figure). There, the signal would first be processed through a low-noise, fast operational amplifier. An antialiasing filter would remove some unwanted noise and eliminate false signals caused by the convolution of

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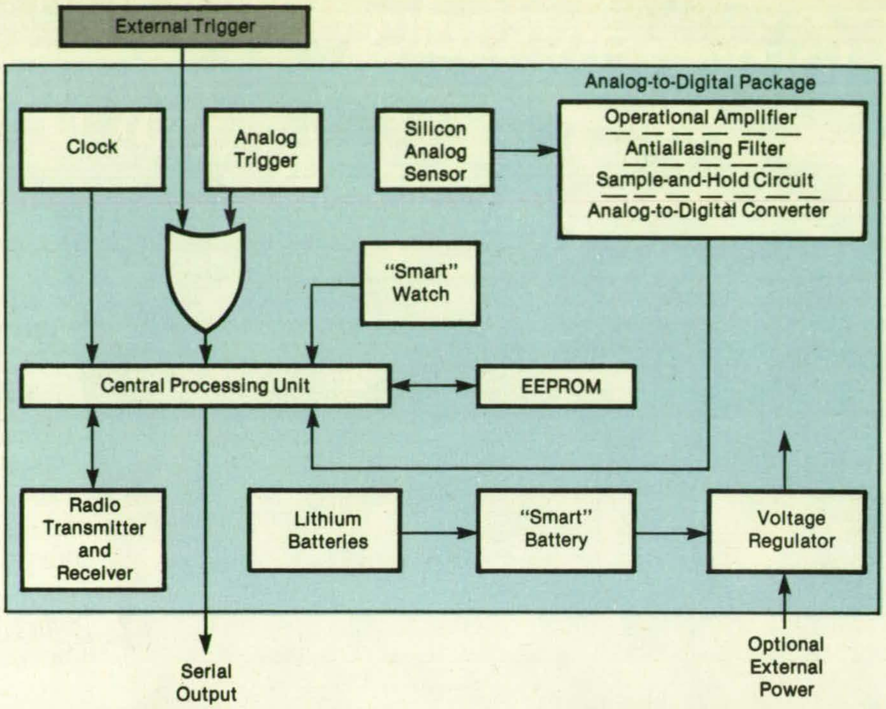
the input-signal spectrum with the spectrum of the output pulse train. A sample-and-hold circuit would store brief (2.8-μs) samples of the filtered signal. Finally, an A/D converter would digitize the sample to 12 bits at a rate up to 125 kHz.

An electronically erasable and programmable read-only memory (EEPROM) would store the digitized signal. A central processing unit (CPU) would control the EEPROM as well as retrieval of the stored data through either direct serial electrical output or a radio transmitter.

Lithium batteries or an optional external source would provide power. The "smart" battery would take over if the main lithium batteries or the external source were to fail. The voltages of all power sources would be regulated.

A clock would synchronize the system and operate an analog trigger, which would start and stop the acquisition of data. Optionally, an external trigger could be used for this purpose. The "smart" watch would keep time in hundredths of seconds, hours, days, months, and years. It would monitor the main power supply and, if it found the voltage going low, would switch to its own lithium battery so that it could keep running.

This work was done by Roy W. Mustain of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 13 on the TSP Request Card. MSC-21521*



The **Integrated Analog-to-Digital Package** is essential to the conceptual data-acquisition system. A commercial component, the package offers high speed and precision. Data could be retrieved directly through a serial output port or remotely via a radio transmitter.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Hypercube-Computer Analysis of Electromagnetic Scattering

The capabilities of hypercube and parallel processing are demonstrated.

A report describes the use of the Mark III Hypercube computer to analyze the scattering of electromagnetic waves. The purpose of this study was to assess the utility of parallel computing in such computation-intensive problems as those of large-scale electromagnetic scattering. Two electromagnetic codes based on different algorithms were converted to run on the Mark III Hypercube.

The first code implements a finite-difference, time-domain solution of Maxwell's curl equations. This code can simulate the propagation of an electromagnetic wave into a volume that contains a dielectric or conducting object. The incident wave is tracked as it propagates by executing the finite-difference version of the curl equations in each cell in a three-dimensional lattice in which the scattering object is embedded.

The relative independence of the finite-difference iteration in each cell in the lattice enables a decomposition of the problem over the spatial domain. The parallel code uses the same global lattice as that constructed by the corresponding sequential code but divides the lattice into blocks of nearly equal dimensions. Neighboring blocks are assigned to nodes that are directly connected. This decomposition scheme assures that each node performs its discrete field updates either with resident information or with information communicated by a node directly connected to it.

The second code is the Numerical Electromagnetics Code (NEC-2), which embodies a frequency-domain method and was developed to analyze the electromagnetic responses of antennas and other metallic structures. This code uses integral equations to compute the currents induced on a structure by sources or incident fields. It combines an integral equation for smooth surfaces with one specialized for wires to provide for the mathematical modeling of a wide range of structures. The use of these equations with boundary-condition equations on the surface produces a general integral equation in which the unknowns are the longitudinal currents on segments of wires and the two perpendicular components of the surface currents on patches. These equations are solved numerically by a technique based on the method of moments. The solution requires the inversion of a matrix, the size of which increases with the size of the scattering object in relation to the wavelength.

In the parallel implementation, the inversion is performed by a factorization of the matrix into a right triangular matrix by a series of orthogonal Householder transformations. Since the computations within one column of the matrix are independent of those in others, the matrix to be factored is distributed to the nodes of the hypercube computer by columns. At each step of the transformation, one more column of the working matrix becomes inactive. To assure optimum balance of the computational load, the assignment of columns is performed in card-dealing fashion. The newly factored matrix overwrites the working matrix, thereby conserving storage of data.

The NEC code was tested by application to a quarter-wave monopole antenna on a pedestal over a perfect ground represented by 130 radial wires. The far radiation fields were computed and compared with those obtained from sequential computations and exact solutions.

One way to measure the performance is to compare the time required to solve the problem on one node versus the time required to solve the same problem on 32 nodes. A speedup factor is then determined by dividing the single-node time by the 32-node time. For the finite-difference code, speedup factors of up to 30 have been measured. The method-of-moments code, which requires more interprocessor communication because of the manipulation of matrix elements, exhibited speedup factors of up to 26.

Another measure of performance is the comparison of the maximum size of the problem that can be solved on the hypercube versus that on a conventional sequential computer. On the VAX 11/750 computer, the largest finite-difference lattice that can run in a typical user's dynamic allocation of memory contains about 192,000 unit cells; on the Mark III Hypercube with 32 active nodes, the largest lattice contains about 2,048,000 unit cells.

This work was done by J. E. Patterson, P. C. Liewer, R. H. Calalo, and F. Manshadi of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Electromagnetic Scattering Analysis on a Hypercube Parallel Architecture," Circle 59 on the TSP Request Card.*
NPO-17551

Physical Sciences

Hardware, Techniques, and Processes

Wide-Field, Two-Stage Optical System

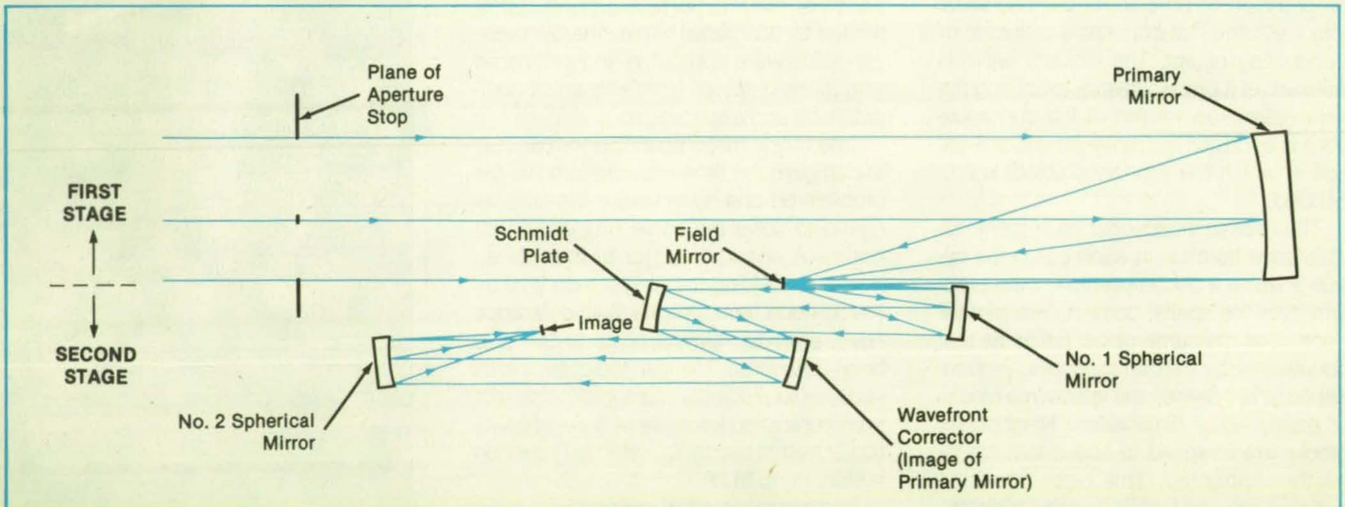
Wide-field, triple-Schmidt optics correct errors in large primary mirror.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed telescope would offer a wide field of view, yet be relatively inexpensive to manufacture. The design, in the form of three Schmidt cameras, offers a 10-degree strip field of view, a single large-diameter collecting aperture, four spherical mirrors, and two diamond-turned aspheric mirrors in a relatively compact configuration. The uniqueness of this design (see figure) is twofold. First, the large-diameter Schmidt corrector plate, normally located at the center of curvature of the large spherical primary mirror, is relayed to a subaperture Schmidt corrector plate to be shared by all three Schmidt cameras. This reduces the number of large-diameter optics to just the primary mirror. Second, another subaperture diamond-turned corrector is located at the conjugate to the primary mirror for the purpose of removing the effects of fabrication errors on the primary mirror surface.

In a conventional telescope, a mirror of large aperture is difficult and costly to manufacture to the tolerances needed for high-acuity imaging because of its large mass and surface area. In the new telescope, the image of the large primary spherical mirror is relayed onto a smaller mirror surface, where a phase correction is applied to remove wavefront errors caused by the imperfect primary mirror. The primary mirror therefore need not be of the high quality that would otherwise be required. This concept enables cost-effective implementation of large-diameter optics by relaxing fabrication requirements. The design described is an f/3 triple-Schmidt with one large-diameter optic and is the first wide-field optical system to incorporate the theory of two-stage optics.

This work was done by Paul K. Manhart, Apostolis A. Deslis, Steve A. Macenka, and James B. Breckinridge of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, Circle 29 on the TSP Request Card.*
NPO-17392



Transference of the Large-Diameter Schmidt Corrector Plate to a smaller element makes this wide-field optical system suitable for the application of the two-stage optics theory.

Ballistic-Electron-Emission Microscope

Buried interfaces are investigated with high spatial resolution.

NASA's Jet Propulsion Laboratory, Pasadena, California

The ballistic-electron-emission microscope (BEEM) employs scanning tunneling-microscopy (STM) methods for the nondestructive, direct electrical investigation of buried interfaces, such as the interface between a semiconductor and a thin metal film.

With the STM system, an emitting electrode in the form of a sharp tip is held within a few angstroms of the surface of a sample and scanned piezoelectrically along the surface, while the current of electrons tunneling quantum-mechanically between the tip and the sample is measured. A computer uses the measured current as a function of position to produce a topographic image of the surface of the specimen in the form of a contour, false-color, or other map.

In the BEEM (see Figure 1), there are at least three electrodes: the emitting tip, a biasing electrode, and the collecting electrode, which receives the current that crosses the interface under investigation. A signal-processing device amplifies the electrode signals and converts them into a form usable by the computer. Like the STM, the BEEM can produce spatial images of the surface by scanning the tip; in addition, it can provide high-resolution images of the buried interface under investigation. Spectroscopic information may also be extracted by measuring the collect-

ing-electrode current as a function of one of the interelectrode voltages.

For example, Figure 2 shows measurements taken with the tip positioned just above the surface of a gold layer deposited on negatively doped silicon. The left plot shows collector-electrode current as a function of the voltage between the base and emitter electrodes. The voltage of the transition from region A to region B is correlated with the height of the energy barrier at the interface between the gold and the silicon. The slope of region B is determined by both the thickness of the gold and the quality of the interface between the gold and the silicon. The right plot shows collector-electrode current as a function of emitter-electrode current for several values of emitter-base tunneling voltage. The plot shows the linear dependence of collector current on emitter current.

This work was done by William J. Kaiser and L. Douglas Bell of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 14 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-17384, volume and number of this NASA Tech briefs *issue, and the page number.*

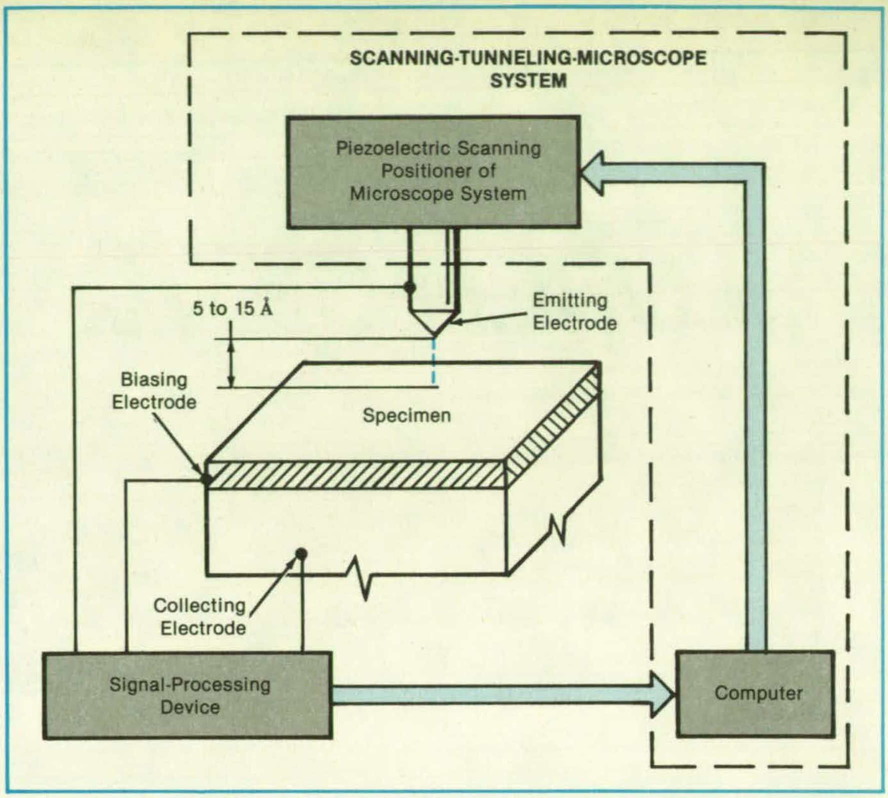


Figure 1. The **Ballistic-Electron-Emission Microscope** is a scanning tunneling microscope equipped with extra electrodes and signal-processing equipment to extract additional information about the specimen.

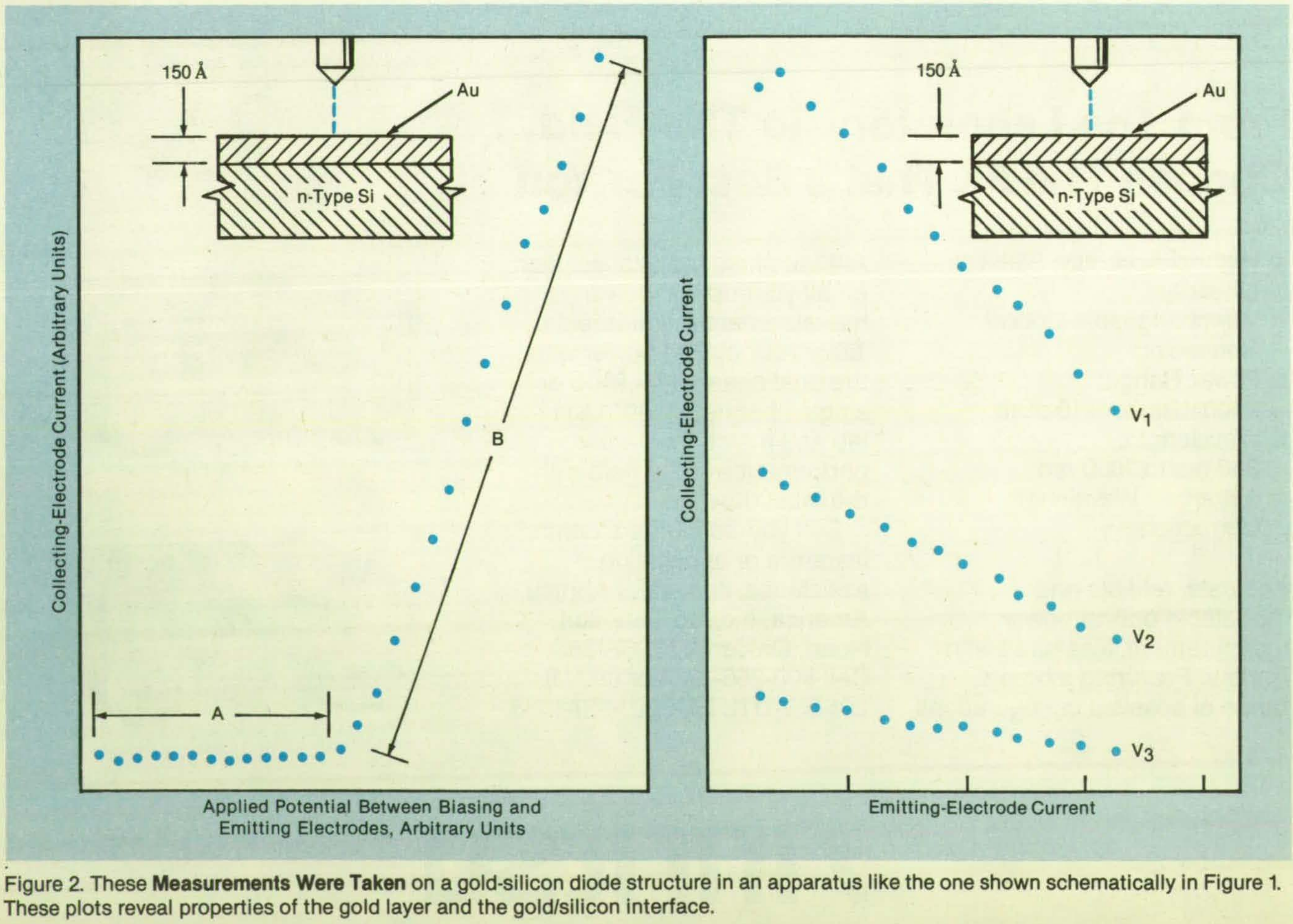


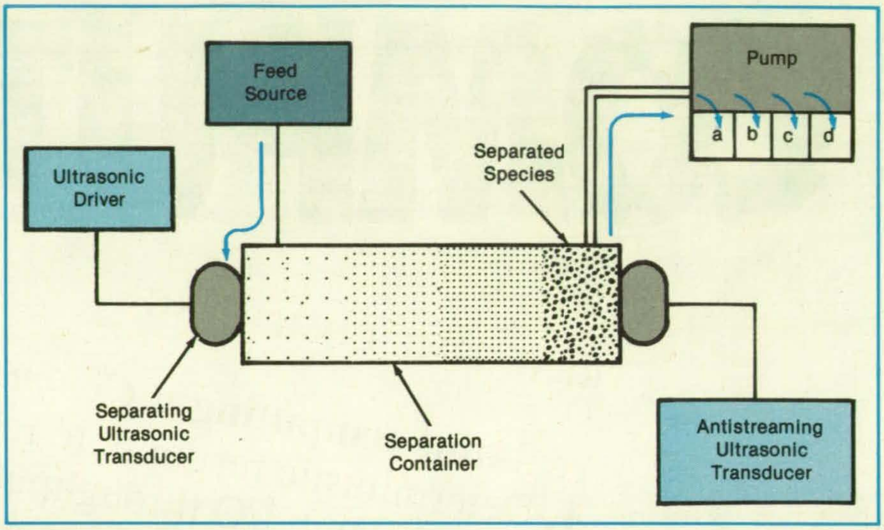
Figure 2. These **Measurements Were Taken** on a gold-silicon diode structure in an apparatus like the one shown schematically in Figure 1. These plots reveal properties of the gold layer and the gold/silicon interface.

Acoustophoresis — A New Separation Concept

Ultrasound separates chemical species.

Langley Research Center, Hampton, Virginia

A concept under development may expand the technology of chemical separation to include ultrasonic-radiation pressure. When an ultrasonic wave passes through a medium, it carries energy and momentum: the loss of energy by the wave is accompanied by a transfer of momentum to the substance that carries the energy. For example, since molecular chains have different nonlinear properties and absorb ultrasonic energy through such mechanisms as resonance relaxation, the forces on these chains depend on the frequency of the sound. Therefore, by selecting a specific frequency, one can "tune in" to a selected chemical property — acoustic absorption — and separate chemical species (with different absorption coefficients) that may be impossible to separate by other means.



The **New Technique** separates species of particles according to their ultrasonic properties.

For the separation of particles, the choice of acoustic wavelength will change the acoustic scattering process and thus the force imparted to the suspended particles. As the frequency is varied from low to high, the larger particles (those with higher scattering cross section) will scatter the sound first, followed by the smaller particles. Thus, the larger suspended particles will be swept from the liquid first by the transferred momentum.

As shown in the figure, the feed source supplies the liquid medium containing the desired species in mixture with other species. The liquid is fed into the separation container. An ultrasonic transducer connected to an ultrasonic driver sends an ultrasonic wave into the liquid, exerting on the desired species an acoustic-radiation force that depends on the absorption of the acoustic wave and on nonlinear interactions. Thus, the propagation results in a separation based on the absorption (or scattering) of the acoustic wave.

The separated species are removed sequentially by a pump and placed in different compartments (a,b,c,d). If the absorption in the different species is nearly equal, then acoustic streaming may mix the liquid, preventing separation. To minimize that effect by counteracting the streaming, a second transducer is driven by an antistreaming device. In effect, the second acoustic wave can be tuned to a frequency different from that of the first, and to a different amplitude, thereby producing a high-resolution "shearing" of the liquid into its separate species.

The acoustophoresis concept can utilize not only bulk compressional waves but also surface waves or boundary waves between a solid (or liquid) container wall and the subject liquid. The free surface of the subject liquid acts as a waveguide that contains the input acoustic energy.

This work was done by Joseph S. Heyman of **Langley Research Center**. *For further information, Circle 43 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center (see page 16]. Refer to LAR-13388

Compact, Broadband Infrared Spectrometer

A double-pass Schmidt optical system is stable and light in weight.

NASA's Jet Propulsion Laboratory, Pasadena, California

A large-aperture, wide-angle, broadband infrared spectrometer is compact and light in weight. It is based on a double-pass version of the Schmidt optical system that acts as both a collimator and a camera. Because the optical system is contained in a piece of solid glass, it is mechanically and thermally stable.

Radiation in the wavelength range of 850 to 2,500 nm is fed from optical fibers into the spectrometer through a flat entrance surface. (As shown in the figure, the cable of optical fibers appears to coincide with an array of PbS detectors and to face a blocking filter in front of the array but in fact is displaced from the array out of the page.) Because of the high index of refraction of the glass relative to that of air, the angle of divergence of the marginal rays in the glass is significantly less than it is before it enters. This is one of the reasons the instrument can be made to operate at the relatively-large numerical aperture of 0.51.

The diverging rays are roughly collimated by the primary mirror surface, which is coated with aluminum protected by a black epoxy paint overcoat. A narrow stripe across the center is left uncoated by aluminum to prevent reflection of the incoming radiation from this stripe directly back onto the array of detectors. The roughly collimated rays are turned about 90° by total internal reflection at the folding surface, then pass out of the glass optical system through an aspherical Schmidt

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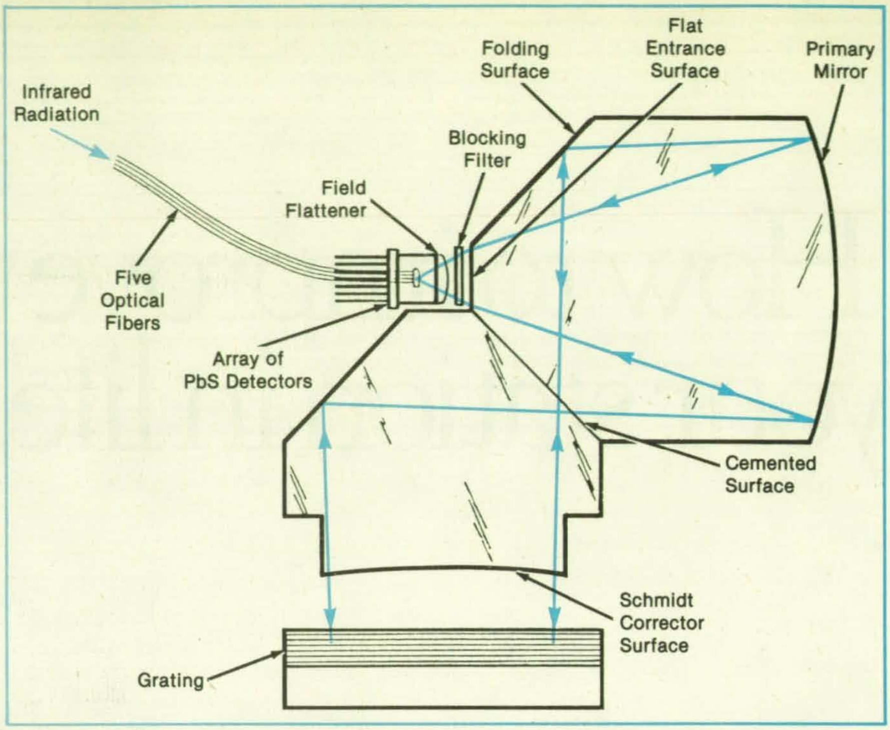
corrector surface that makes the roughly collimated beam well collimated.

A diffraction grating then disperses the radiation angularly according to wavelength and reflects it back through the optical system to the array of PbS detectors. Functioning as a camera on the return pass, the optical system focuses the spectrum on the array, where wavelength is read as a function of position (picture-element number). The spectral range is covered by 45 picture elements.

The optical system is made of water-free fused silica to minimize absorption of infrared radiation. Although in principle it could have been made from a single, solid piece, in practice it has to be made in two pieces that are then cemented together. Fabrication would be easier and simpler if even more cemented surfaces could be used so that each optical surface could be ground and polished like a single lens element. However, more cemented surfaces are not used because optical cements absorb in the infrared.

This work was done by Norman A. Page and Mary L. White of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 17 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 16]. Refer to NPO-17562



The **Double-Pass Design** makes this spectrometer compact. Because most of the optical system lies within a solid piece of fused-silica glass (actually, two pieces cemented together), the instrument is rugged.

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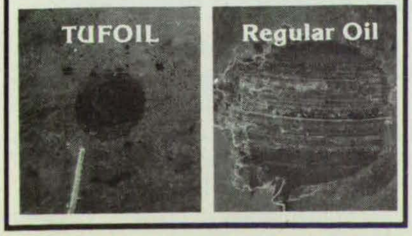

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These substances are useful for making heat- and fire-resistant polymers.

Langley Research Center, Hampton, Virginia

One goal in the synthesis of high-performance thermoplastic polymers for adhesives and graphite-reinforced composites is to develop composites with enhanced properties, including toughness, thermal stability, and meltprocessability. Cyclotriphosphazene-based monomers and polymer precursors have led to the development of high-temperature materials. Cyclotriphosphazene-derived monomers, polymer precursors, and polymers are becoming important from both industrial and scientific points of view.

The presence of the phosphazene moiety in cyclotriphosphazene-based monomers and polymer precursors is expected to impart special properties in desired high-performance materials containing inorganic backbones for aerospace applications. The initial phase of research on these materials has been devoted to the development of various cyclotriphosphazene-derived monomers and polymer precursors, including halo-, nitro-, and amino-derivatives, which are potentially useful for making various polymers.

Efficient procedures for the synthesis of isomeric novel amine- and nitro-terminated trisaryloxycyclotriphosphazenes [especially tris(4-nitrophenoxy)tris(phenoxy)cyclotriphosphazenes and tris(4-aminophenoxy)tris(phenoxy)cyclotriphosphazenes] from hexachlorocyclotriphosphazene were developed for various reaction conditions. Chemical characterizations were performed by use of Fourier-transform infrared spectroscopy, nuclear magnetic resonance, mass spectrometry, and elemental analysis.

Tris(4-nitrophenoxy)tris(phenoxy)cyclotriphosphazenes with melting points of 111 to 112 °C and 133 to 135 °C were obtained. A process was developed to separate these compounds from the reaction products, resulting in isomers that had sharply-defined melting temperatures. The low-pressure hydrogenation of the separated nitro compounds in the presence of platinum oxide catalyst reduced the nitro groups to the corresponding tris(4-aminophenoxy)tris(phenoxy)cyclotriphosphazenes that had melting temperatures of 131 to 133 °C and 105 to 106 °C, respectively.

The substances produced are useful for obtaining heat- and fire-resistant polymers for composites, adhesives, molding powders, and coating laminates. These compounds might also be used in structures (e.g., secondary structures in aircraft), in the construction of spacecraft, and in the electronics and computer industries.

This work was done by Terry L. St. Clair and Devendra Kumar of **Langley Research Center**. *For further information, Circle 44 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 16]. Refer to LAR-13819

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Survey of Infrared-Absorbing Coatings

Carbon black and silicon carbide grit are low reflectance additives

A report presents the results of a survey of candidate materials for use as attenuators of stray radiation in far-infrared telescopes. More than 40 reflectance spectra at 17° incidence, in the wavelength range from 20 to 500 μm, were obtained from a variety of coatings, binders, and additives.

Coating specimens were prepared on optically flat pieces of 6064-T6 aluminum, 2.5 by 2.5 by 0.32 cm. Liquid coatings were applied in drops, then smoothed to uniform thickness with a modified razor blade. Powder coatings were chopped or fluffed with a razor blade, then spread with a broad blade. Some solid coatings (glass microballoons and SiC grit) could be spread smoothly by surface tension of a few drops of propanol. Each solid coating was bound to the substrate with a thin, dilute insulating varnish that produced no detectable infrared absorption in the amount used.

The thicknesses of the coatings were measured with a microscope and a comparator. Roughnesses were measured optically and with a profilometer. A Fourier-transform interferometer was equipped with three beam splitters, two light sources, and two photodetectors to measure overlapping reflectance spectra that, together, covered the full spectral range.

Some additives alone or in combination with certain binders exhibited specular reflectances less than 0.1 at all wavelengths of interest: these include carbon black; No. 180 SiC grit; No. 80 SiC grit; Black Suede binder consisting of black iron oxide in polyurethane, with carbon black and No. 80 SiC grit; Chemglaze Z-306 binder consisting of carbon-black-pigmented polyurethane, with No. 80 SiC grit; and ECP-2200 binder consisting of jagged silica particles in a silicone binder containing a proprietary black dye, with carbon black and No. 80 SiC grit. The SiC particles are believed to enhance attenuation by imparting roughness to the surface and by scattering the incident radiation into the bulk of the coating, thereby increasing the optical path length.

Other coating materials that were tested include an electroless nickel plate with nitric acid etch, a graded-index-of-refraction polyurethane coating, nylon flock, and TIBr powder. In addition, DeSoto Black (or equivalent) carbon-black-pigmented polyurethane shows promise as a binder, possibly as a replacement for Black Velvet (or equivalent).

This work was done by Sheldon M. Smith of **Ames Research Center** *and Richard V. Howitt of Teletrac, Inc. Further information may be found in NASA TM-88204 [N88-28757], "Survey of Material for an Infrared-Opaque Coating."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 16]. Refer to ARC-11767.

Electrochemical Study of Corrosion of Painted Steel

Resistor-and-capacitor circuit models represent evolving properties of coated specimens.

Electrochemical experiments on the corrosion of painted 4130 steel are described in a report. This study is part of a general development of the ac-impedance method for measurement of the properties of coated metals.

Specimens of the bare or painted steel were exposed for 30 to 60 days to an aqueous solution of 3.5 percent NaCl buffered at pH 5.4. Every 2 days, the ac impedance of each specimen in the solution was measured as a function of frequency from 1 mHz to 90 kHz. The dc polarization resistance was also measured.

Two equivalent circuits developed as mathematical models of the ac electrical properties of the corroding metal/paint system consist of fairly simple combinations of resistors and capacitors. By a least-squares procedure, values of the resistances and capacitances were fitted to the impedance-versus-frequency data for each specimen at each measurement interval, so that the evolution of the properties of each corroding surface could be characterized.

Two different types of specimen were tested during each of three phases of the study. In phase I, the steel was coated with zinc-rich primer 0.8 mil (0.02 mm) thick or red lead oxide primer 0.6 mil (0.015 mm) thick. In phase II, the coat was either 0.6 mil zinc-rich primer with 0.7 mil (0.018 mm) epoxy/polyamide topcoat or 0.5 mil (0.013 mm) red lead oxide primer with 0.7 mil topcoat. In phase III, the coat was either 1.6 mils (0.04 mm) zinc-rich primer with 2.3 mils (0.06 mm) topcoat or 1.9 mils (0.05 mm) red lead oxide primer with 2.6 mils (0.07 mm) topcoat. For comparison, an uncoated specimen was also tested.

The ac-impedance method proved effective in the evaluation of specimens in all three phases. The dc method was useful for the specimens of phase I (primer only) and correlated well with the ac method for those specimens. The dc method did not work well for specimens of phase III. The newer and more complicated one of the two equivalent-circuit models gave an exceptional fit to the impedance data, and the value of one of the capacitors in this model was found to be directly proportional to the rate of corrosion.

In phase I, the zinc-rich primer gave the best protection. In phase II, the specimens with the zinc-rich primer failed first: hydrogen evolved in the primer, causing blisters in the topcoat. In phase III, both combinations of primer and topcoat continued to protect the steel adequately during the entire time of immersion, though both lost electrical resistance (indicating some deterioration). Overall, it appears that both primer/topcoat combinations are adequate and neither is preferred over the other, as long as the primer and topcoat have adequate thicknesses.

This work was done by M. H. Mendrek, R. H. Higgins, and M. D. Danford of **Marshall Space Flight Center**. *For further information, Circle 36 on the TSP Request Card. MFS-27213*

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Electronic Systems

Estimation of Interference in Satellite/Ground Communications

The relative strengths of desired and interfering signals are computed for known orbits.

In the late seventies, the number of communication satellites in service increased, and interference has become an increasingly important consideration in designing satellite/ground-station communication systems. The Satellite Interference Analysis and Simulation Using Personal Computers (AKSATINT) computer program calculates the interference experienced by a generic satellite communications receiving station from an interfering satellite.

Both the desired and the interfering satellites are considered to be in elliptical orbits. The simulation contains computation of the orbital positions of both satellites by use of classical orbital elements, calculation of the look angles of the satellite antennas for both satellites and the elevation angles at the desired-satellite ground-station antenna, and computation of the Doppler effect caused by motions of the satellites and the rotation of the Earth. AKSATINT also computes the interference-to-signal-power ratio, taking into account losses suffered by the links.

After computing the interference-to-signal-power ratio, the program computes the statistical quantities. The statistical formulation of the interference effect is presented in the form of a histogram of the interference-to-desired-signal-power ratio. The program includes a flow chart, a sample run, and results of that run. AKSATINT is expected to be of general use to designers of systems and managers of frequencies in selecting the proper frequencies under interference scenarios.

The AKSATINT program is written in BASIC. It was designed to operate on the

IBM Personal Computer AT or compatibles and has been implemented under MS DOS 3.2. AKSATINT was developed in 1987.

This program was written by Anil V. Kantak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 11 on the TSP Request Card.*
NPO-17500

Physical Sciences

Computing Orbital Viewing Parameters

A program yields data on the times of visibility of celestial objects.

The QUIKVIS computer program calculates the times during an orbit around the Earth when geometric requirements are satisfied for observing celestial objects. The observed objects may be fixed (e.g., stars) or moving (Sun, Moon, planets). QUIKVIS is useful for preflight analysis by those needing information on the availability of celestial objects to be observed.

QUIKVIS performs two types of analyses: One is used when specific objects are known, the other when targets are unknown and potentially useful regions of the sky must be identified. The results are useful in selecting candidate targets, examining the effects of observation requirements, and doing gross assessments of the effects of the right ascension of the ascending node (RAAN) of the orbit. The results are not appropriate when high accuracy is needed (e.g., for scheduling actual mission operations).

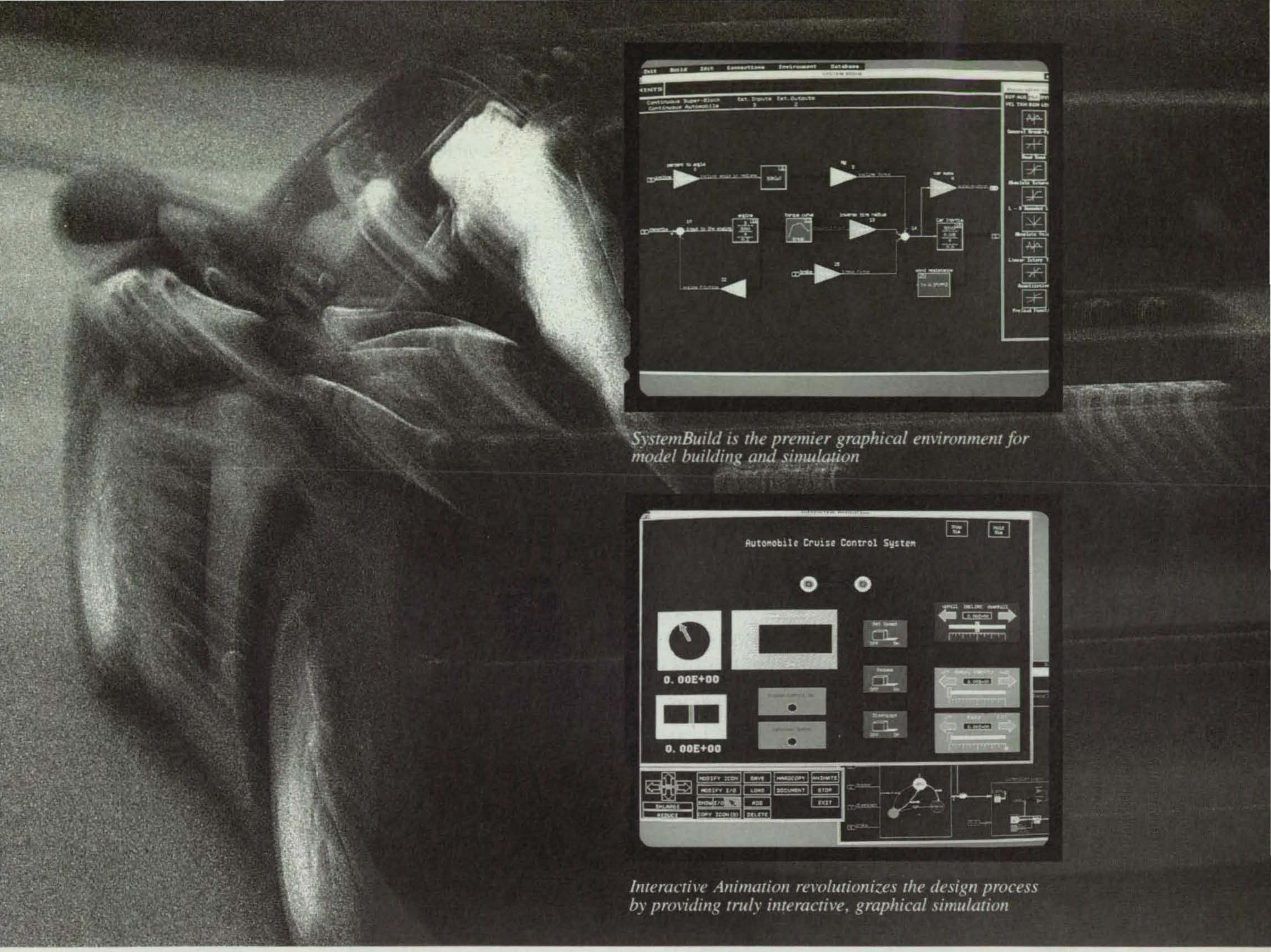
The duration of an observation is calculated as a function of date, RAAN, and geometric requirements. The RAAN can be varied to account for the effects of an uncertain launch time. The semimajor axis and inclination of the orbit are constant throughout the run. A circular orbit is assumed, but a simple modification of the program will permit the use of eccentric orbits.

The geometric requirements that can be processed are (1) the minimum angle between the line of sight to the object and the horizon of the Earth, (2) the minimum angle between the line of sight to the object and the velocity vector of the spacecraft, (3) the maximum angle between the line of sight to the object and the zenith direction, and (4) the presence of the spacecraft in the shadow of the Earth. The user must supply a date or range of dates, the altitude and inclination of the spacecraft, up to 700 observation targets, and any geometric requirements to be met.

The primary output is the duration per orbit when conditions are satisfied for individual targets. Options create printer-plot maps of potentially useful regions of the sky and bar graphs showing when individual and composite requirements are satisfied. Line-printer output is presented in visually convenient formats. Data-file output is available for use by post-processing programs, such as plotters and observation scheduling programs.

QUIKVIS is written in FORTRAN 77 for batch or interactive execution and has been implemented on a DEC VAX 11/780 computer operating under VMS with a central-memory requirement of approximately 500K of 8-bit bytes. QUIKVIS was developed in 1986 and revised in 1987.

This program was written by Charles Petruzzo of **Goddard Space Flight Center**. *For further information, Circle 116 on the TSP Request Card.*
GSC-13083



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Mechanics

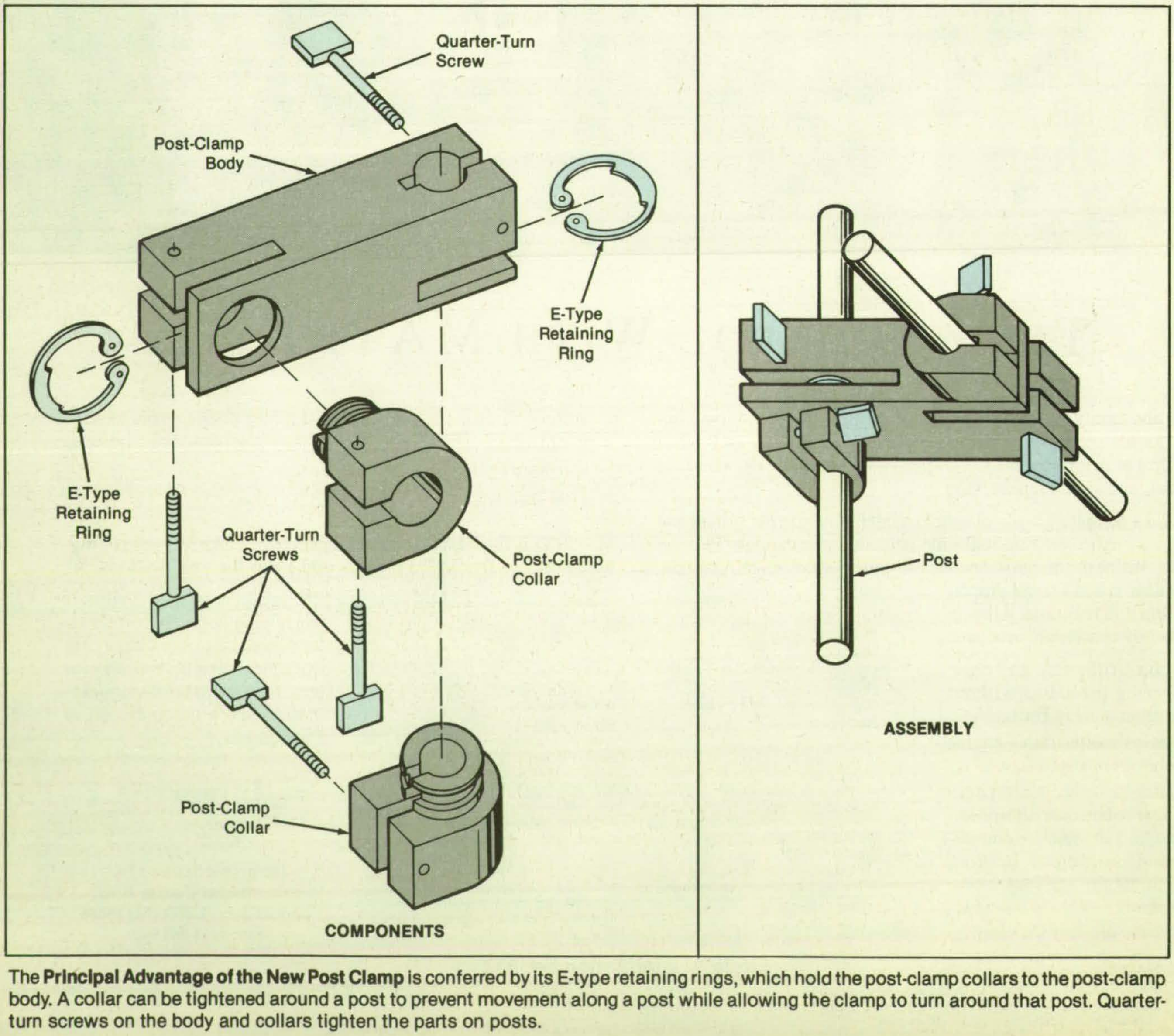
Post Clamp With Attached Collar

The collar makes adjustment of optical components easier and faster.

Lewis Research Center, Cleveland, Ohio

A new clamp for optical posts can reduce the time required to set up optical components. Like earlier clamps, the new clamp joins a pair of perpendicular posts supporting a laser, lens, reflector, or other optical component and enables the posts to be rotated in perpendicular planes so that the orientation and position of the component can be adjusted. The new clamp can be adjusted with only half the number of steps required by older clamps and separate post collars. Inasmuch as adjustments have to be made again and again for many components in an optical setup, the reduction in the number of steps adds up to a significant reduction in setup time. Moreover, the new clamp, unlike some older ones, does not tend to mar a post.

The post-clamp body retains post-clamp collars with E-type retaining rings (see



The **Principal Advantage of the New Post Clamp** is conferred by its E-type retaining rings, which hold the post-clamp collars to the post-clamp body. A collar can be tightened around a post to prevent movement along a post while allowing the clamp to turn around that post. Quarter-turn screws on the body and collars tighten the parts on posts.

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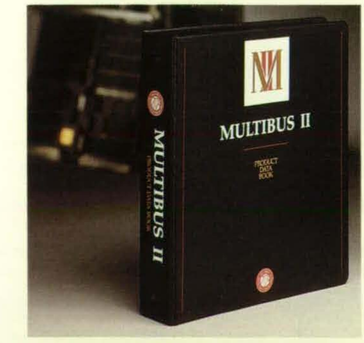

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figure). A mounting post is inserted through the hole in a post-clamp collar and the corresponding hole in the post-clamp body. Quarter-turn screws in the collar and body are tightened to reduce the diameters of the holes and thereby grip the post. A second post is inserted in the other hole in the body (at a right angle to the first post) and clamped in the same way.

To translate and rotate the clamp on a post, a user follows this procedure:

- Loosen the quarter-turn screws on the body and collar that secure the clamp assembly to the post. Slide the clamp along the post to the desired axial position. Tighten the screw in the post-clamp collar.
- Rotate the clamp on the post to the desired angular position. Tighten the screw in the post-clamp body.

One of the advantages of the new clamping assembly is that the loosened body can even be suspended on, and rotated about, the tightened collar. Thus, for example, the user can rotate the body on a vertical post without supporting it from below with a separate collar or by hand to prevent it from falling along the post. This convenience is not offered by older clamps.

The new collar makes contact with the post uniformly around its circumference, thus distributing the gripping force evenly. In some older types of collar, in contrast, it is necessary to drive a thumbscrew directly into contact with the post to secure it, applying a concentrated force on a small area of the post. If excessive torque is applied to these thumbscrews, it is possible to mar or scratch the post if the thumbscrew is made of a harder material than the post, making subsequent readjustments of the clamp at the same spot even more difficult.

This work was done by John Karl Ramsey and Erwin H. Meyn of **Lewis Research Center**. *For further information, Circle 115 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 16]. Refer to LEW-14862

Measuring Diameters of Large Vessels

A computerized apparatus produces accurate results quickly.

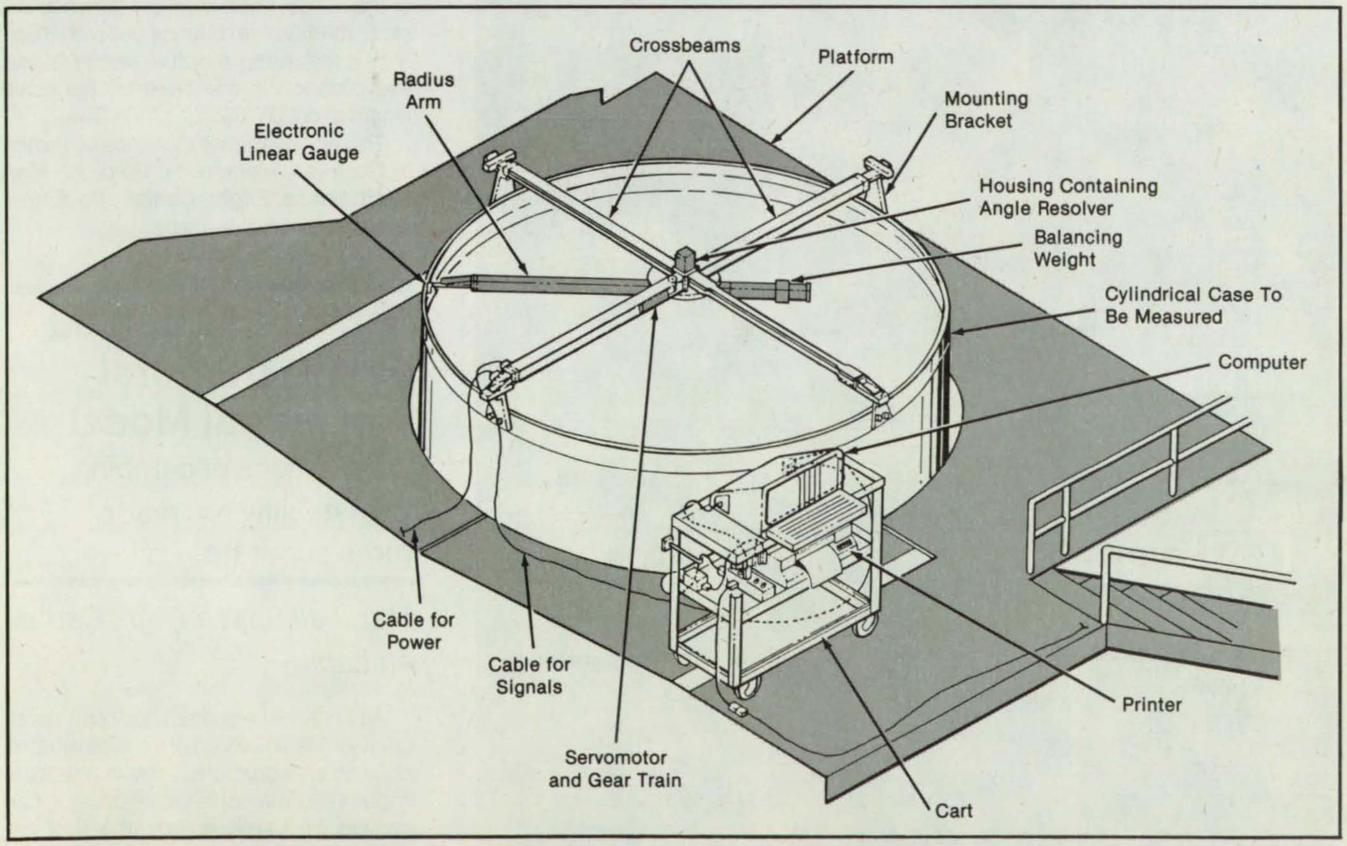
Marshall Space Flight Center, Alabama

An apparatus measures the diameter of a tank or other large cylindrical vessel, without a priori knowledge of the exact location of the cylindrical axis. The apparatus produces a plot of the inner circumference, an estimate of the true center of the vessel, data on the radius, the diameter of a best-fit circle, and the negative and positive deviations of the radius from the circle at closely spaced points on the circumference. It eliminates the need for time-consuming and error-prone manual measurements.

A crossbeam assembly is bolted to the vessel by brackets (see figure). Suspended from the center of the crossbeam assembly is a movable radius arm. A servomotor and gear train rotate the arm so that it pivots about an axis at the intersection of the crossbeams. As the arm rotates, an electronic linear gauge at the end of the arm is spring-loaded against the inner wall of the vessel. The gauge extends and retracts to follow the wall contour, generating an electrical signal that represents the radius at any instant. The signal is fed through a cable to a computer and printer on a cart.

The circumferential speed of the measuring tip is about 5 in./s (12.7 cm/s). An angle resolver on the shaft that rotates the radius arm generates an electrical signal that represents the rotational position of the arm. This signal is also fed to the computer.

The computer thus obtains data on the length of the arm as a function of the angular position of the arm as it sweeps around the vessel. From the data, the computer calculates the radii, diameter, true



The **Intersection of the Crossbeams** need not be positioned exactly at the center of the vessel. The time required to set up the apparatus for measurements is therefore much shorter than it would be for manual measurements of the radii from a precisely determined center. The computer processes the data from the automatic measurements to find the center.

center, and deviations from true circularity. The computer also controls the operation of the apparatus by turning the power switch on and off to start and stop the measurements.

This work was done by James R. Currie, Ralph R. Kissel, Charles E. Oliver, Earnest C. Smith, John W. Redmon, Sr., Charles C. Wallace, and Charles P. Swanson of **Marshall Space Flight Center**. *For further information, Circle 82 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-28287.

Using Ruby Balls as Fiducial Marks

A combination of basic and advanced techniques yields a new capability for inspection.

Marshall Space Flight Center, Alabama

A technique for the measurement of small flaws on the surfaces of bearings involves the use of ruby balls as standards of length. Heretofore, styluses with ruby balls at their tips have been used, but in a tactile method in which probes are moved across suspect areas in attempts to detect defects by feeling them.

In the new technique, a surface is first inspected with fluorescent penetrant dye to reveal flaws. A ruby ball of known diameter is placed near a flaw that has to be measured. The flaw and ball are observed through a magnifying video system that can "freeze" the image.

When the scene is illuminated with a filtered borescope light, the ruby ball emanates a distinct glow that can be seen on the video monitor. Two lines are drawn on the monitor screen to enclose the image of the ball. The distance between the lines is measured in picture elements, and the known diameter of the ball is divided by the distance in elements to obtain the scale length (true distance per picture element) of the image. Then lines are drawn to enclose the flaw, the distance between these lines is measured in picture elements, and this distance is multiplied by the scale length to obtain the size of the flaw.

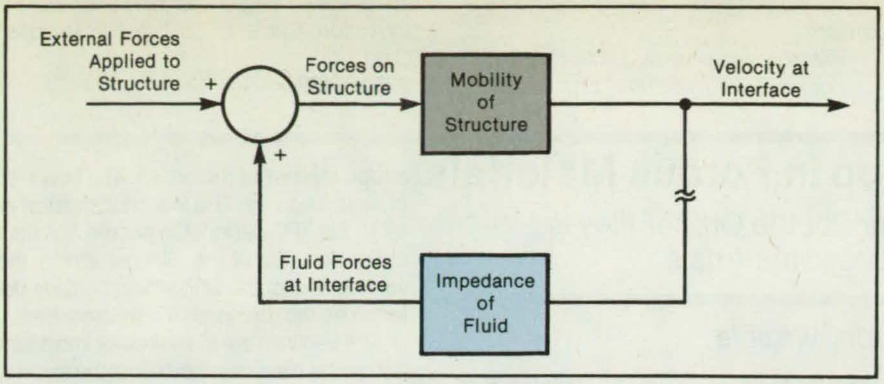
This work was done by Nance M. Painter of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29394

Improved Coupled Fluid/Structural Dynamical Model

Calculations of damping or instability are made more accurate.

Marshall Space Flight Center, Alabama

An improved algorithm has been developed for the simulation of coupled motions of fluids and structures. This is a topic of widespread interest because coupling can convert the kinetic energy of a fluid into mechanical vibration and can cause instability in some ranges of flow. An example of this phenomenon that can be observed in



The **Interactions Between the Fluid and the Structure** are represented by coupled mathematical models. The forces and velocity at the interface are constrained to be compatible in both models at each time step.

many homes is the vibration of a loosely-mounted water pipe at some faucet settings.

Simulation requires great care in the treatment of damping (or resonant gains), frequency being a less important consideration. The fluid in contact with the structure causes some mass loading of the structure and some reduction of vibrational frequency relative to that of the unloaded structure.

It is difficult to couple the mathematical models of the structure and fluid because they involve different types of equations. The nonlinearities of the fluid model usually require numerical solutions in the time domain, using finite time steps. The usual approach is to alternate the solution between the fluid and structure and to choose very small time steps. This approach results in a phase shift, which leads to erroneous values of damping, even though errors in frequency are small.

A minimum requirement for correct simulation of damping is that the forces and velocities at the interface be compatible in the models of the structure and fluid at each time step. The improved algorithm, which conforms to this requirement, involves a fluid-transient model, a structural modal/transient model, and an algebraic impedance/coupling subalgorithm.

The velocity of the structure at the end of each time step is computed, based on the initial position, velocity, modal force, and change in modal force during the time step. The change in modal force has two parts, one of which is a function of time and would occur with no change in the velocity at the interface. The second part is the change in force due to a change in the velocity at the interface.

The interaction between the mathematical models of the fluid and structure are illustrated in the figure. Solving the equations of the fluid subsystem with constant velocity, one obtains the forces at the interface. These are added to externally-applied structural forces to compute the modal force and obtain an estimate of modal velocity. Using the structural mobility (the partial derivative of velocity with respect to force) and the impedance of the fluid system (the partial derivative of force with respect to velocity), the estimate of velocity can be corrected to the value that results in compatible forces and velocity at the interface at the end of the time step. Then using the corrected velocity, the equations of the fluid system can be resolved for the correct change in the force at the interface. A new value for modal displacement can also be found (for use in the structural-transient block).

The use of this algorithm greatly improves the computational stability. Some residual error is caused by the assumption

Circle Reader Action No. 307

that during each time step, the correction to force and velocity is a linear function of time. The errors appear in the solution as errors in the frequency of the system rather than as errors in the damping of the system.

This work was done by James R. Fenwick of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 15 on the TSP Request Card.*
MFS-29439

Predicting Pressure Drop in Porous Materials

Methodology to predict flow under Shuttle Orbiter tiles is applicable to other porous and fibrous materials.

Langley Research Center, Hampton, Virginia

The thermal-protection system (TPS) of the Space Shuttle Orbiter includes a strain-isolation pad (SIP) between the tiles and the underlying surface. The SIP material is a thin mat made of very small fibers primarily aligned either parallel or normal to the structural shell of the orbiter. The flow rate of air through the TPS is a critical parameter in the TPS design. On ascent, the flow characteristics of the SIP determine the venting rate of the SIP, which partially determines the forces on the thermal tiles.

The venting rate is especially important during the transonic portion of the ascent, when the normal shock can rapidly pass over a tile. The large drop in pressure across the shock imposes maximum dependence on the venting capabilities of the TPS. The difference in pressure may tear the tile from the orbiter if the SIP cannot vent quickly enough.

During descent, some parts of the Orbiter experience large local pressure gradients that are constant for significant periods of time. These local gradients produce flow through the SIP. The flow characteristics of the SIP is one element in determining how much hot air will circulate under the TPS. Evaluation of the performance of the SIP requires a knowledge of the pressure drop in the fibrous SIP material.

Overall, the engineering aspects of flows in porous media are not well understood. In critical applications, the designer must rely heavily on experimental data. There has been a program at Langley to provide reliable experimental data on representative portions of the TPS. The data were used in a mathematical model to predict the internal flows for various TPS configurations. However, the data on flow in the SIP were not adequate for all situations. There were no data on the effects of changes in ambient pressure or of changes in the thickness of the SIP due to vertical movements of the tile.

Accordingly, an experimental program to provide additional data was initiated. The new data includes the effects of both large changes in ambient pressure and limited vertical movement of the tile. The pressure drop through a sample of SIP material at conditions covering most of its operating envelope was measured. The experiment simulated the flow of air beneath a tile exposed to a strong surface pressure gradient.

The pressure across the SIP was varied from near 0 to 1.38×10^4 Pa (2 psia). Testing was at constant levels of ambient density from atmospheric to 13.6 percent of the atmospheric value. A theory was developed to predict the drop in pressure based on the drag of the individual fibers. A simple correlation method for the data was also developed.

The methodology developed will help in predicting the flow characteristics of the many SIP flow geometries in the Shuttle

Orbiter tile system. It will help in predicting venting characteristics of tile assemblies during ascent and the leakage of hot gas under the tiles during descent. The predictive philosophy developed should be useful in the study of the mechanics of flows through fibrous and porous media, and the procedures should be applicable to purged fiberglass insulation, dialysis filters, and other fibrous and porous media.

This work was done by Pierce L. Lawing of **Langley Research Center**. *For further information, Circle 51 on the TSP Request Card.*
LAR-14105

Determining Spatial Coordinates by Laser Ranging

Three range-measuring lasers arranged in a triangle measure the location of a point.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method for the determination of the coordinates of an object uses three laser rangefinders arranged in a right angle so that they define a coordinate system. A set of three measurements of the distances (ranges) of a retroreflector on the object from the three rangefinders provides sufficient information to calculate the coordinates of the retroreflector in the coordinate system defined by the rangefinders. If at least three noncollinear retroreflectors are attached to the object, the orientation of the object can also be determined. Potential applications include the observation and control of large structures, robotics, and machine vision.

The calculation of the coordinates from the ranges is based on the law of cosines from trigonometry and the Pythagorean theorem. Using the variables defined in the figure, the angle α_x between the X-axis and the measured range vector R_B from the origin to the object is given by

$$\alpha_x = \cos^{-1}[(R_B^2 + a^2 - R_A^2)/2aR_B]$$

The X-coordinate of the retroreflector is given by

$$x = R_B \cos(\alpha_x)$$

Similarly, the angle α_y between the Y-axis and range vector R_B is given by

$$\alpha_y = \cos^{-1}[(R_B^2 + c^2 - R_C^2)/2cR_B]$$

The Y-coordinate of the retroreflector is given by

$$y = R_B \cos(\alpha_y)$$

The Z-coordinate of the retroreflector is given by

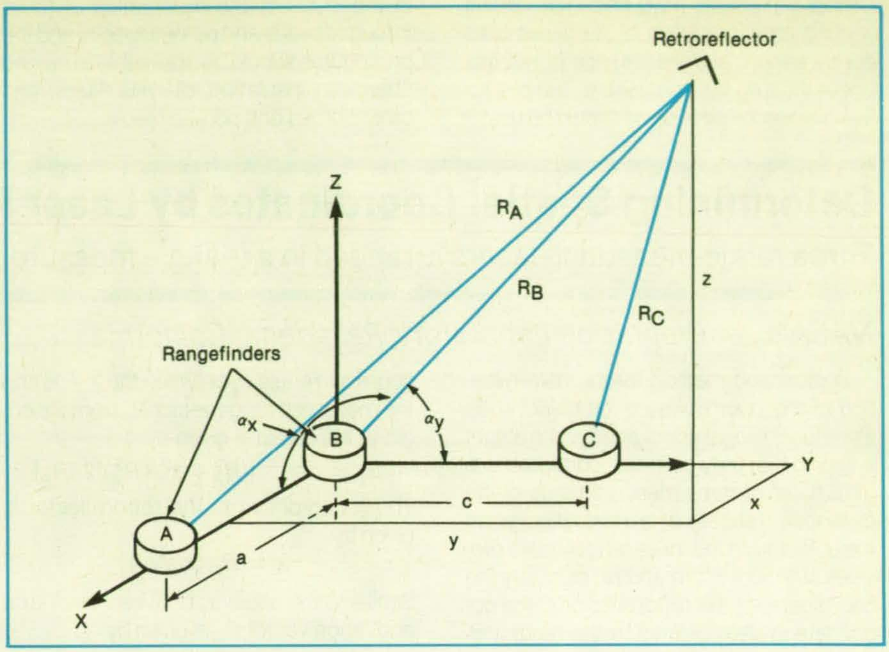
$$z = (R_B^2 - x^2 - y^2)^{1/2}$$

If the object carries three or more suitably placed retroreflectors, the orientation of the object can also be determined by measuring the coordinates of each of the retroreflectors in the same manner. For accurate results, the distances between the retroreflectors must be large compared to the range resolution of the rangefinders. Furthermore, care must be taken that the various range measurements are correctly assigned to the various retroreflectors.

This work was done by Larry L. Schumacher of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 5 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to
Edward Ansell

 Circle Reader Action No. 377



The **Spatial Coordinates** of a retroreflector can be determined from a set of three range measurements taken simultaneously by three laser rangefinders.

Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17436, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

More About Multiple-Boundary-Condition Testing

Measured shapes of vibrational modes are used to update mathematical models.

A report extends the discussion of the multiple-boundary-condition vibrational testing technique described in a recent issue of *NASA Tech Briefs.* As its name implies, this technique involves the vibrational testing of a complicated structure under various combinations of boundary conditions, each of which yields experimental data on a different part or parts of the mathematical model of the structure. With proper choices of the multiple boundary conditions, the technique enables the experimental validation of the structural mathematical model for structures that can be ground tested by current "state-of-the-art" techniques due to the influence of the terrestrial environment, namely air and gravity.

In the previous literature on multiple-boundary-condition vibrational testing, only the eigenvalues (in effect, the frequencies of the vibrational modes) have been used in the correlation and update of the mathematical model. In this report, the emphasis is on further refinement of the mathematical model by use of the differences between the measured eigenvectors (i.e., the displacements of various places on the structure in the vibrational modes) and the eigenvectors predicted by the model that is to be so refined.

The structure is represented by a finite-element mathematical model of mass matrix M and stiffness matrix K. The vibrational modes (eigenmodes of the model) are characterized by the eigenvalue matrix L and the eigenvector matrix P. From the basic matrix•vector equations of motion and the orthogonality of P with respect to K and M, the authors derive the following two equations for the relationships among small changes in K, L, M, and P, ignoring second- and higher-order differential terms:

$$dL = P^T(dK)P - LP^T(dM)P$$

and

$$(K - LM)dP = L(dM)P - [LP^T(dM)P]MP - (dK)P + [P^T(dK)P]MP$$

where T denotes the transpose. The intermediate objective is then to solve these equations simultaneously to obtain dK and dM; that is, to update the parameters K and M of the mathematical model on the basis of the difference dP between the meas-

ured and assumed eigenvectors.

The ultimate objective is to update the estimates of the physical parameters of the structure (areas, moments of inertia, and the like), rather than the elements of the mathematical model, which are more numerous. For a model of N degrees of freedom, these matrix equations provide $N+1$ equations for each eigenvector and corresponding eigenvalue. Thus, the system is overdetermined, resulting in multiple estimates of the desired parameters. This overdetermination provides the leeway for the selection of boundary conditions.

The authors present a numerical example in which multiple-boundary-condition test data are used to make the approximate parameters of a mathematical model of a flexible beam of four different cross sections converge toward the correct values. The effects of several different boundary conditions are illustrated. Issues for future research include the choice of proper subsets of information for the estimation of the parameters of interest and the selection of the boundary conditions that will yield the correct data.

This work was done by Chin-Po Kuo and Ben K. Wada of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Multiple Boundary Condition Test (MBCT): Identification With Mode Shapes," Circle 16 on the TSP Request Card.* *NPO-17574*

Computational Fluid Dynamics for Helicopters

Powerful computer codes are undergoing development.

A report reviews the development of computational fluid dynamics (CFD) for the prediction of airflow around the rotary wings of helicopters. CFD computer codes, developed during the past 15 years, are now widely applied in industry. With them, it is now practical to make complete rotor computations, including transonic unsteady and three-dimensional effects, without resorting to empiricism and extensive libraries of data.

There is now no lack of codes, the report notes. The small-disturbance full-potential rotor code, FPR, is the simplest and most efficient. It models the essential unsteady physics and is accurate for high-Mach-number, low-lift conditions. ROT22 and TFAR1 are quasi-steady, nonconservative codes for high-lift conditions in which unsteady effects are not dominant. TFAR2, an unsteady code, has no such limitation; it produces accurate solutions to unsteady problems even though it is nonconservative.

For problems that entail very strong shocks or require detailed modeling of the near wake, it is necessary to develop codes that implement the Euler and Navier-Stokes equations of flow. New Navier-Stokes codes should eventually provide an understanding of three-dimensional stall effects. An example of this line of development is the TFAR3 code, which solves the Euler equations of transonic flow about a helicopter rotor.

The report reviews progress in the following endeavors:

- Prediction and verification of flows under various operating conditions;
- Calculation of interactions between rotor blades and vortexes;
- Analysis of viscous, transonic flows about airfoils; and
- Study of the formation of vortexes at the tips of rotors.

Computational fluid dynamics cannot yet treat realistic combinations of rotors and bodies — that is, complete rotorcraft. However, algorithms are constantly improving, and supercomputer technology is advancing at a dazzling pace. Thus, the foundation is being laid for eventual computational analysis of complete rotorcraft.

This work was done by F. X. Caradonna and W. J. McCroskey of **Ames Research Center**. *To obtain a copy of the report, "The Development of CFD Methods for Rotor Applications," Circle 104 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 16]. Refer to ARC-12143.

Machinery

Hardware, Techniques, and Processes

Articulated Suspension Without Springs

Wheels negotiate bumps and holes with minimal tilting of the vehicle body.

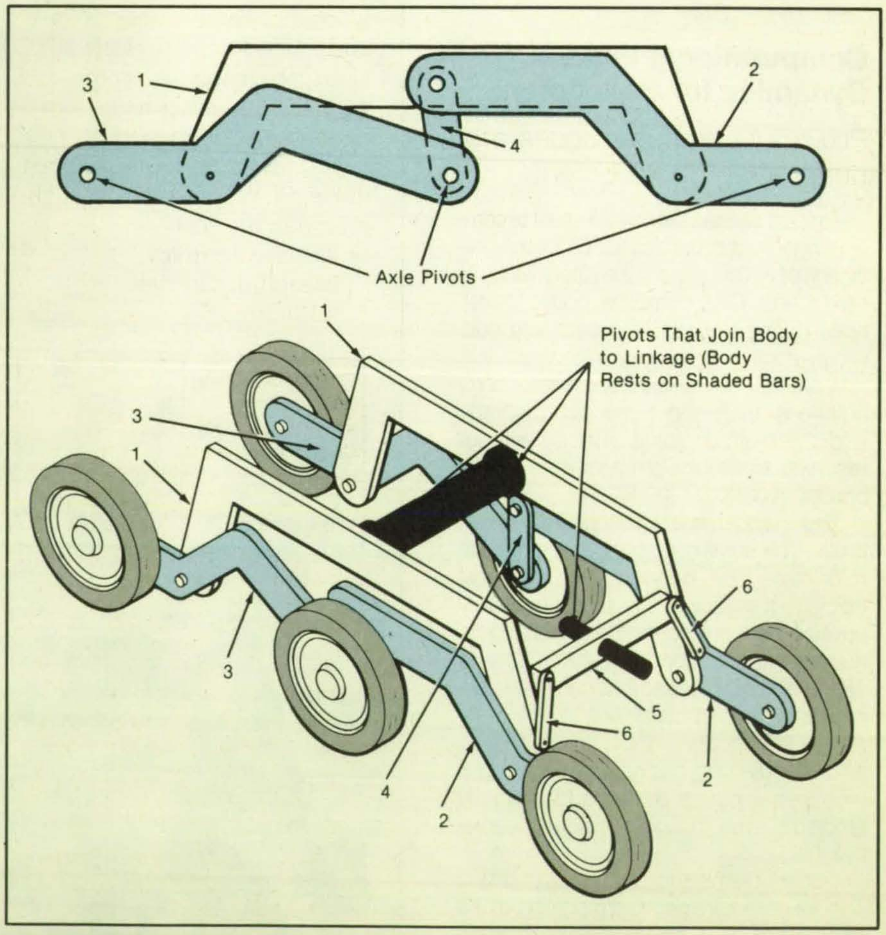
NASA's Jet Propulsion Laboratory, Pasadena, California

A springless suspension for a vehicle allows its wheels to cross bumps and other obstacles independently while maintaining a nearly uniform distribution of weight and traction on the wheels. Spring suspensions, in contrast, shift disproportionate amounts of weight to the most deflected wheels.

In the new suspension, a wheel can climb an obstacle as high as 1½ times its diameter without excessive tilting of the chassis. It therefore provides a highly stable ride over rough ground for such vehicles as wheelchairs, military scout cars, and police and fire robots. Moreover, it does not subject the vehicle to the oscillations common in spring suspensions.

A system of levers distributes the weight to the wheels (see figure). The levers are sized to distribute equal or other desired portions of the load among the wheels. Link 1, with pivots at each end, connects two axle bogies, links 2 and 3. Link 3 is a true bogie, having an axle at each end. Link 2 is like link 3 except that it is connected to the middle axle through link 4 instead of directly.

The same type of linkage is used on both sides of the vehicle. A body unit joins the two sides at pivots at the middles of links 1. At the front or rear of the body unit, link 5 pivots crossways to average the positions of the left and right sides. Links 6 and 7 join link 5 to the left and right links 1 at or near



The **Linkage** on either side of the vehicle allows six wheels to rise and fall nearly independently of each other. Additional links (bottom) connect the two side mechanisms and support the body of the vehicle.

the bogie pivots.

As the wheels traverse bumps and holes, the bogies pivot to follow the terrain. The mechanism averages the wheel displacements so that the body unit is subjected to minimum rocking.

This work was done by Donald B. Bickler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 42 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 16]. Refer to NPO-17354.

Automatic Calibration of Manual Machine Tools

A modified scheme uses data from multiple positions and eliminates tedious positioning.

Marshall Space Flight Center, Alabama

The modification of a computer program adapts a calibration system for convenient use with manually-controlled machine tools. Developed for use on computer-controlled tools, the unmodified laser-interferometry system requires that the machine-tool axis be set precisely and repeatedly at each of 30 or more predetermined target positions. Such repetitive positioning — often to within one resolution element of 0.0001 inch (0.025 millimeter) — is readily done by numerical control on an automatic machine, but is tedious and time consuming on a manual lathe, milling machine, or jig borer.

Accordingly, an option was added to the calibration program to allow data on random tool-axis positions to be entered manually into the computer for reduction. Instead of setting the axis to the predetermined positions, the operator merely sets it at a variety of arbitrary positions.

At each point, the operator notes the position or dimension indicated on the dial of the tool and enters that value into the computer. The interferometer also measures the position. The computer compares the entered value with the measured value and calculates the error and the variance of the error. The computer combines the calculations for all the data points and determines the uncertainty in the indicated position for the region of axis travel covered by the points.

This work was done by Rex D. Gurney of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29380

Nonobstructive Damping for Parts Vibrating in Flows

Vibrational energy is dissipated by strategically located holes filled with particles.

Marshall Space Flight Center, Alabama

Vibration-prone parts in fast-flowing liquids or gases can be damped by a simple provision: drill or cast small holes in them and fill the holes with particles. The particles absorb the vibration energy without obstructing flow.

The damping holes add little to the costs of manufacturing the parts. They reduce the masses of parts because the masses of the inserted particles are less than those of the materials removed to make the holes. They function as well at cryogenic temperatures as they do at ordinary temperatures.

The holes should be positioned according to analysis of the nodes and antinodes of the vibrations. The sizes and numbers of required holes are functions of the thicknesses of walls, the amplitudes and frequencies of vibrations, and the damping requirements.

In a demonstration, four holes 1 millimeter in diameter were drilled in an inlet splitter vane for liquid oxygen in the Space Shuttle main engine. The holes were filled with such particles as steel shot, ceramic shot, tungsten powder, and nickel powder. The vanes were vibrated at high frequency and amplitude in a shaker both before and after the filling of the holes. The filling of the holes was found to have reduced the amplitude of vibration by a factor of more than 5.

This work was done by Hagop V. Panossian of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29572

Circle Reader Action No. 669

Fabrication Technology

Rounding and Aligning Tubes for Butt Welding

An easy-to-use tool helps to ensure a solid, reliable joint.

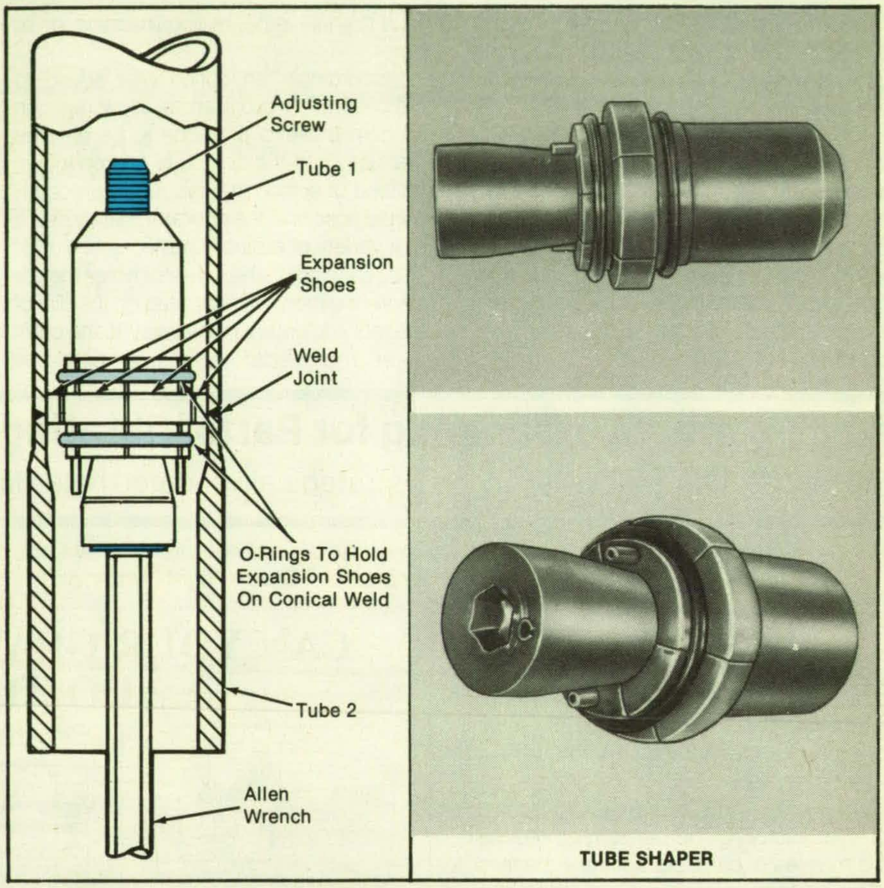
Marshall Space Flight Center, Alabama

A tool similar to an automobile-tailpipe expander corrects out-of-roundness in tubes before they are butt-welded and holds the tubes in position during welding. Afterward, the tool can be collapsed for extraction from the tubing.

An operator inserts the tool — possibly at the end of a long allen wrench — into the abutting tubes so that its expansion shoes straddle the joint (see figure). Using the allen wrench, the operator turns the adjusting screw to push the expansion shoes outward against the tubes. The shoes deform the ends of the tubes slightly, making them almost perfectly round and aligning the axes. The joint between the tubes can then be welded from the outside.

When the weld has been completed, the operator turns the allen wrench in the opposite direction. The shoes collapse inward until they are reduced in diameter sufficiently to permit the tool to be withdrawn easily from the tube through which it was inserted.

This work was done by Richard H. Burley and Glenn H. Burow of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29363



Two Tubes are rounded and aligned with each other by the expansion shoes. After use, the shoes are retracted so that the tool can be withdrawn, even through a tube narrower than its mate.

Dummy Cup Helps Robot-Welder Programmers

A cheap copy is substituted for an expensive cup when collisions are likely.

Marshall Space Flight Center, Alabama

A dummy gas cup is used on the torch of a robotic welder during programming and practice runs. Made of metal or plastic (see figure), the dummy cup is inexpensive and durable. It can withstand bumps caused by programming errors, and it can be sized for special welding jobs within limited clearances.

After the robot has been satisfactorily programmed, the dummy cup is replaced by a ceramic cup of the same dimensions for actual welding. The robot can then move through its welding procedure without damaging the costly and fragile ceramic cup.

Programming is done more quickly with the dummy cup. The programmer does not have to be concerned with bumping the cup and can therefore program with greater speed and confidence.

This work was done by Stephen S. Gordon of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29499

The **Dummy Cup Has the Same Size and Shape** as those of the real ceramic cup. This dummy cup is machined from aluminum and anodized with a black finish.

Superplastically Formed Titanium Hat-Stiffened Panels

Beading increases the critical buckling strain.

Langley Research Center, Hampton, Virginia

Recent advances in the superplastic forming of some metals have made it possible to fabricate new shapes. Superplastic forming enables the design of structures that use mass more efficiently. Parts that have intersecting compound contour surfaces can be made; it would be impossible to fabricate such parts by more conventional methods.

Four hat-stiffened titanium panels with two different stiffener configurations were fabricated by superplastic forming and weld brazing and were tested under moderately heavy compressive loads. The panels had the same overall dimensions but differed in the shape of the hat stiffener webs; three panels had stiffeners with flat webs, and the other panel had stiffeners with beaded webs. The two configurations were made in the same basic mold, starting with sheets of the same nominal thickness. The panels were short enough to prevent general buckling.

The hat-stiffened panel shown in Figure 1 is typical of an aircraft structure. The primary function of the material in the webs of the hat stiffener is to support the load-carrying caps. For this purpose, the webs should be made as thin as possible, yet have enough bending stiffness to provide adequate support for the caps. For a panel with stiffener caps and webs made from a single sheet of material, the requirement for thin webs conflicts with the requirement for a cap with high local buckling strain. Beads in the stiffener webs, shown in Figure 2, increase their transverse bending stiffness to provide more support for the cap and produce a web with a high local buckling strain.

A general panel-sizing computer code was used to evaluate the mechanical responses of the conventional and beaded hat-stiffened panels. Analysis indicated that the local buckling strains of the flat stiffener webs were considerably lower than the general buckling strains of the panels or the buckling strains of the caps. The analysis also showed that when the webs of the hat stiffeners are beaded, they cease to be the critical elements for local buckling, and the buckling strains of the panels are increased. The analytical prediction that the beaded webs would increase the local buckling strengths of the

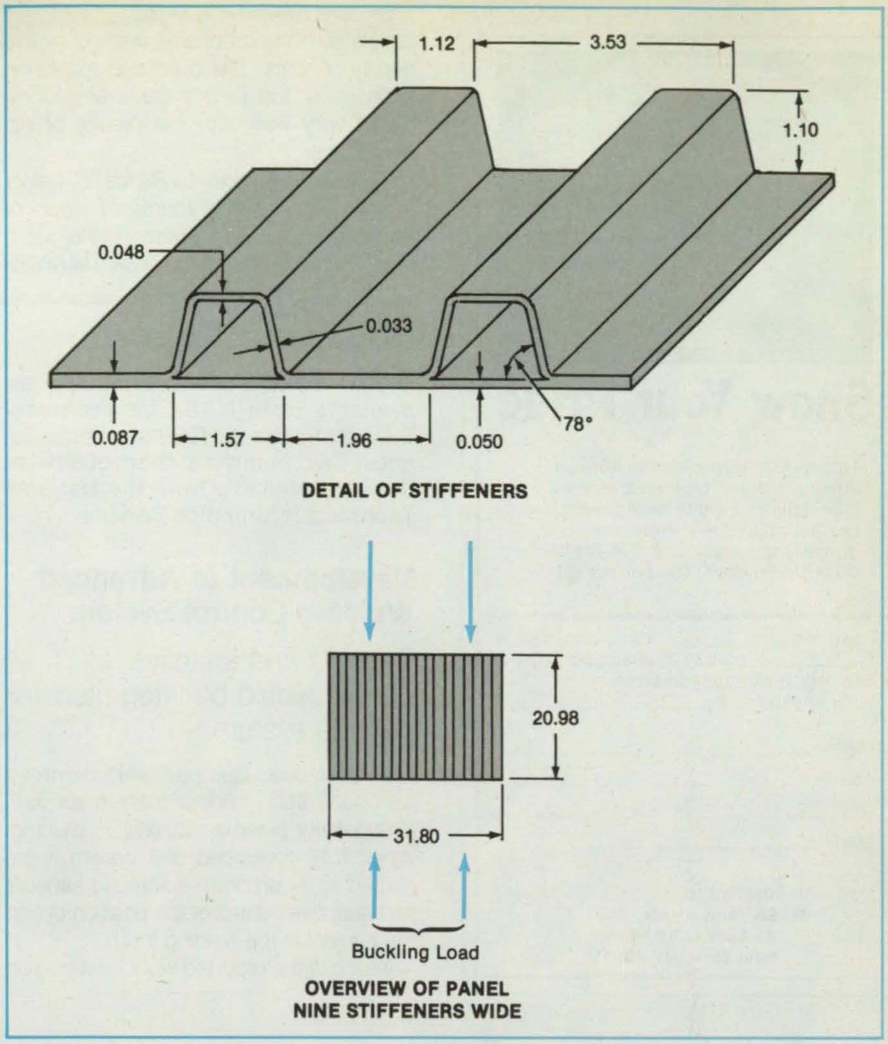


Figure 1. **Geometric Details of a Conventional Hat-Stiffened Panel** are shown, with dimensions in inches.

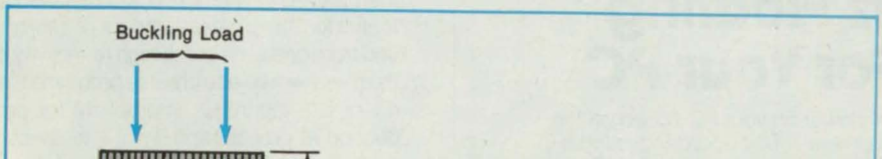


Figure 2. The **Beaded Hat-Stiffened Panel** has higher critical buckling strain than does the conventional hat-stiffened panel. Dimensions are in inches.

panels by 13 percent was verified by the results of tests. The predicted extension stiffnesses and failure loads also compared very well with the results of experiments.

This work was done by Randall C. Davis, Dick M. Royster, and Thomas T. Bales of **Langley Research Center**. *Further information may be found in NASA TM-88989 [N87-18119], "Analysis and Test of Superplastically Formed Titanium Hat-Stiffened Panels Under Compression."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LAR-13814

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Development of Advanced Welding Control System

Sensors and adaptive control would be integrated into the system.

A report describes the development of a next-generation control system for variable-polarity plasma arc (VPPA) welding. When fully developed, the system is expected to incorporate advanced sensors and adaptive control of the position of and the current in the welding torch.

Much of the reported work centered on the development of a thorough understanding of the interrelationships among various welding parameters. This involved experiments to acquire data on the following:

- The effects of the rate of flow of shielding gas on the voltage, plasma pressure, and heat imparted to the workpiece;
- The effect of the frequency, duration, and amplitude of reverse current on the cleaning action and the dimensions of the weld band;
- The response and sensitivity of a plasma-pressure sensor at various distances from the body of the welding torch; and
- The maintenance of a constant distance between the torch and the workpiece and the related effects on the size of the weld keyhole, arc voltage, and other parameters.

In addition, telephone surveys were conducted to determine the commercial acceptability of the conceptual control system.

The information in this data base was used to evaluate advanced sensor technologies for the applicability to the control of the VPPA welding process. Although thermography was found to offer the potential for the greatest amount of information from one sensor, the high reflectivity of the metal workpiece creates problems that make this technique impractical for production at present and limits it to specialized applications in the detection of misalignment, misclamping, and unknown heat sinks. Other sensors were found to be more suitable for specific tasks; e.g., a laser-based subsystem to track the weld seam.

Research on the control system focused upon a commercial computer system that provides for multiple processors, a variety of commercial input/output interface circuits, and great flexibility in configuration. The basic computer equipment supports the continuing development of sensing and control equipment and computer programs. Control of the VPPA welding process by schedule, including the tracking of the weld seam by the incorporation of sensor data into an adaptive control scheme, has been demonstrated.

This work was done by General Digital Industries, Inc., for **Marshall Space Flight Center**. *To obtain a copy of the report, "Prototype Demonstration of a Next Generation Welding Control System," Circle 119 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-26106

Method for Automatic Downhand Welding

A control algorithm satisfies several welding-process requirements simultaneously.

A report discusses part of the control concept for the downhand-welding system described in a recent issue of *NASA Tech Briefs*. (In downhand welding, the parts to be welded and the welding head are always oriented to keep the face of the weld as nearly horizontal as possible so that gravitation helps to keep the molten metal in the joint.) The report presents the mathematical basis of a control algorithm for a computer-aided design/computer-aided manufacturing system that would perform downhand welding.

The algorithm would be one of several intended to meet various requirements of the welding process. Based in part on a series of homogeneous transformations between frames of reference, positions, and orientations, it treats the six-degree-of-freedom robot arm with welding-head end effector and the two-degree-of-freedom workpiece-positioning mechanism as an overall robotic system of eight degrees of freedom. The welding path is first defined with respect to the frame of reference of the workpiece, then converted via an iterative solution method to the angles and/or extensions of the joints of the equivalent eight-degree-of-freedom robotic linkage.

The algorithm is the third in a sequence of three developmental algorithms, in which each algorithm provides more control than does its predecessor. The first algorithm provides, in terms of the eight degrees of freedom of the robotic system, for the maintenance of the required relative position and velocity of the workpiece and welding torch. The additional constraint imposed by minimization of the weighted-sum-of-squares joint-angle displacement is used to eliminate the redundancy inherent in the eight-degree-of-freedom mechanism. The second algorithm provides for the required position and velocity of the torch and for the simultaneous orientation of the part for downhand welding. The third algorithm is similar to the second except that it also provides for the correct orientation of the weld-wire-feeding mechanism.

An operator would "teach" the welding path to the system by specifying the position and orientation of the welding torch with respect to the workpiece at each of a large number of points. The operator would not have to maintain the wire-feed orientation and would normally not have to maintain the downhand orientation during the training session. In most cases, the algorithm should provide automatically for both of these orientations and for the required welding-torch velocity when it converts the teaching-session data into commands for the robot joints. However, to be assured of the downhand orientation, it may be advisable to verify the welding-path program via a computer simulation.

This work was done by Ken Fernandez of **Marshall Space Flight Center** *and George E. Cook of Vanderbilt University. Further information may be found in NASA TP-2807 [N88-17869], "A Generalized Method for Automatic Downhand and Wirefeed Control of a Welding Robot and Positioner."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. MFS-27209

Wing Covers for Aerodynamic Studies

Techniques, problems, and solutions are described.

A report discusses the construction of thin covers — known as "gloves" in the industry — on the wings of airplanes for use

in aerodynamic studies. The gloves, made of foam cores and fiberglass-and-resin outer layers, contain instrumentation to measure properties of boundary layers, sounds, and pressures. The report focuses on the gloves installed on F-14A and F-15A airplanes, and compares the techniques used to construct these gloves with the technique used to construct a glove on an F-111 airplane during a previous study.

The report begins with a brief history of the flight-research programs for which the gloves were developed. Experiences in the construction and use of the gloves are summarized.

Following the introduction is a section devoted to the program of experiments on the F-14A. The first subsection gives a general description of modifications of the structure and operation of the airplane to accommodate the gloves. The second subsection describes preconstruction tests in flight and on the ground. The third subsection describes glove I, a full-span glove on the upper surface of the left wing. This subsection begins with the techniques used in the following 10 steps of installation of glove I: (1) preparation of the wing, (2) initial bonding, (3) installation of the foam core and fiberglass outer layer, (4) the use of templates to verify the outer surface contours of the gloves, (5) incorporation of plumbing for instrumentation, (6) shaping the gloves to final contours, (7) postcuring and finishing, (8) final placement of instrumentation, (9) final checks and spot finishing, and (10) load tests. This subsection concludes with a description of construction problems and solutions. The fourth subsection describes glove II, a full-span, variable-thickness glove on the right wing. This subsection is abbreviated by reference to similarities with the construction of glove I.

The next section discusses the program of experiments on the F-15A. This section is also abbreviated by reference to similarities with the techniques of construction used in the F-14A program. The final section presents conclusions and recommendations for good engineering practice in general construction, compensation for the characteristics of the vehicle, incorporation of instruments, the use of filler materials, postcuring, the selection of materials, maintenance, and the necessity for skilled construction workers.

This work was done by Marta R. Bohn-Meyer of **Ames Research Center**. *Further information may be found in NASA TM-100440 [N88-21128], "Constructing 'Gloved' Wings for Aerodynamic Studies."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
ARC-12238

Mathematics and Information Sciences

Synchronization Technique for Reception of Coded Data

The shortest sequence of bits likely to be filled with error bursts is examined.

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm improves the synchronization of frames of noisy binary-coded data signals after Viterbi decoding (recovery from the "inner" convolutional code used in the transmission channel) and before Reed-Solomon or other decoding (recovery from the "outer" error-correcting block code) (see Figure 1). Like another synchronizing algorithm in common use, this one is based on comparisons of sequences of correct and erroneous Viterbi-decoded received bits with a known marker sequence that denotes the beginning of a frame of data. Unlike the other algorithm, this one does not require a count of the number of bits in the received sequence that disagree with corresponding bits in the marker sequence.

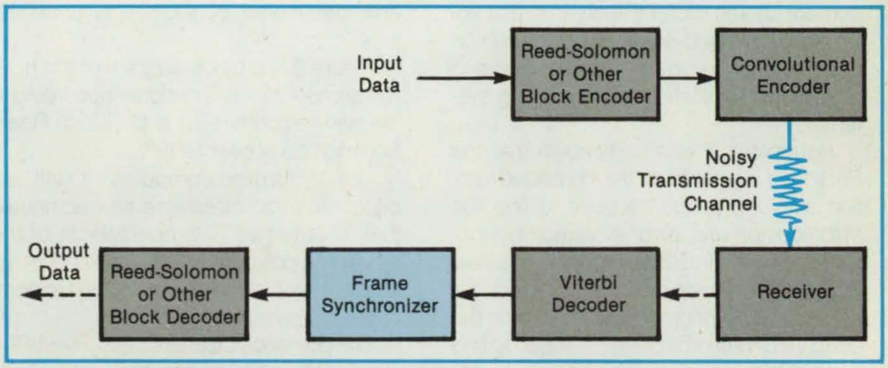


Figure 1. The **Synchronizing Algorithm** operates on the stream of Viterbi-decoded bits to synchronize the frames of data for proper decoding.

Each frame of the block code contains N (typically, about 10,080) bits, of which the first k (typically, about 32) bits constitute the marker. For proper decoding, it is necessary to identify the marker, which could be, for example, a sequence of k zeros. Because noise in the transmission channel can change some of the bits, the problem is to identify a received sequence of correct plus erroneous bits that are likely to represent the marker. To do this, the algorithm specifies the following:

1. Choose a positive integer T (the threshold).
2. Examine the k consecutive received bits starting with the αth bit. Note those bits that disagree with the corresponding bits in the marker sequence.
3. If the distance δ (that is, the number of bits) between the first and last bits that disagree with the marker is greater than T, then reject α as the beginning of a marker; otherwise, retain α as a candidate for the beginning of a marker.
4. If α remains a candidate, then perform a similar examination of the k bits starting with the $\alpha+N$th bit. If $\delta > T$ for this sequence, then reject α or $N+\alpha$ as the beginning of a marker and start anew at $\alpha+1$.
5. If $\delta \leqslant T$ in step 4, then repeat the procedure starting at $\alpha+2N, \alpha+3N, \ldots$. If δ exceeds T in three consecutive trials, then reject α as the beginning of a marker and start again at $\alpha+1$.

This algorithm succeeds because of a statistical property of Viterbi-decoded sequences: Errors tend to occur in bursts. Thus, when the marker is identified correctly, the bits that disagree with the

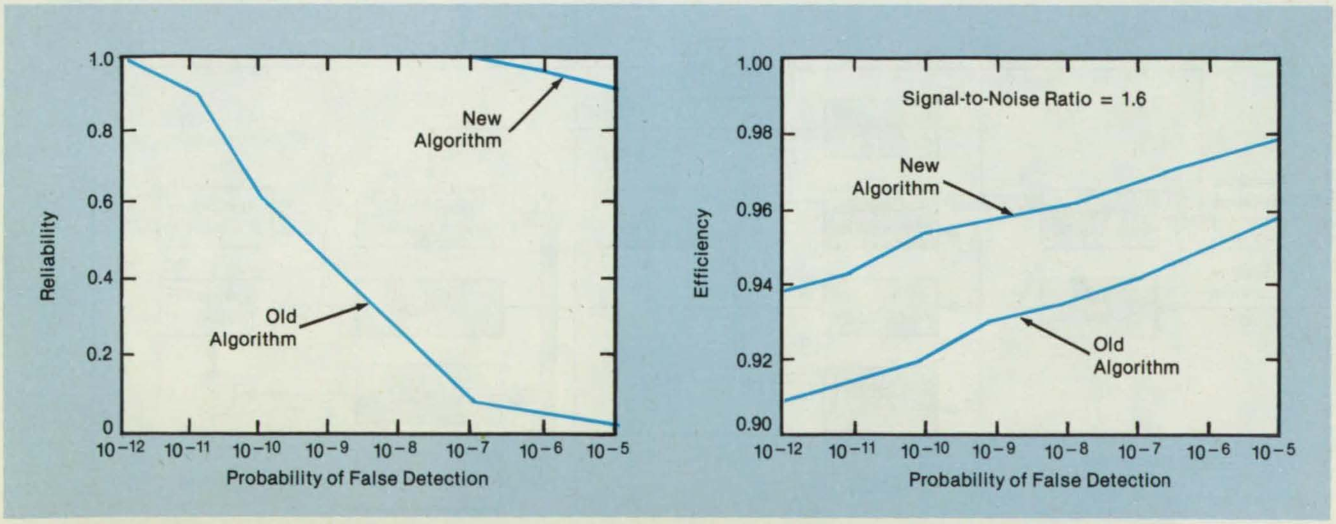


Figure 2. The **Reliability and Efficiency** of the new synchronizing algorithm are greater than those of the previous algorithm at a given probability of false detection of the marker.

marker tend to occur in proximity to each other, and it therefore usually suffices to identify the beginnings and ends of the sequences of erroneous bits.

The performance of the algorithm was estimated probabilistically, using various signal-to-noise ratios, an assumed statistical distribution of burst errors, and values of T from 1 to 21. In comparison with the previous method, this algorithm proved significantly more reliable and efficient in the detection of the marker (see Figure 2).

This work was done by Mehrdad M. Shahshahani and Laif Swanson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 34 on the TSP Request Card.*
NPO-17037

Simplified Correction of Errors in Reed-Solomon Codes

A new decoder can be realized by a simplified pipeline architecture.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simplified procedure for the correction of errors and erasures in Reed-Solomon codes is expected to result in simpler decoding equipment. This development should widen the commercial applicability of Reed-Solomon codes, which can be used to correct bursts of errors in digital communication and recording systems.

Heretofore, it was well known that the Euclidean algorithm or the continued-fraction algorithm could be used to find the error-locator and error-evaluator polynomials to correct both errors and erasures. Figure 1 is a block diagram of a decoder according to a prior algorithm in which the continued-fraction algorithm is used to find the errata-locator polynomial by replacing its initial condition by the erasure-locator polynomial. The disadvantage of this algorithm is that after the errata-locator polynomial $\tau(x)$ is obtained by continued fractions, a polynomial multiplication is still needed to compute the errata-evaluator polynomial $A(x) = \lfloor S(x)\tau(x) \rfloor$ from the known errata-locator polynomial and the syndrome polynomial $S(x)$, where $\lfloor x \rfloor$ denotes the principal part of x.

The new algorithm is a modified version of the previous algorithm. Here the initial condition of the Euclidean algorithm is replaced by the erasure-locator and Forney syndrome polynomials. This makes it possible to obtain the errata-locator and errata-evaluator polynomials simultaneously and simply by the Euclidean algorithm only; that is, a separate computation of the errata-evaluator polynomial is unnecessary.

Figure 2 is a block diagram of the pipeline architecture of a decoder according to the new algorithm for a (255,223) Reed-Solomon code over GF(2^8).

The syndrome-computation unit accepts received messages and computes their syndromes. The coefficients of the syndrome polynomial $S(x)$ are fed in parallel to the polynomial-expansion unit to compute the Forney syndromes.

The power-calculation unit converts the received 1's and 0's into a sequence of α^k's and 0's, where α is a primitive element of the finite field [in this case, GF(2^8)] over which the Reed-Solomon code is defined. These received 1's and 0's indicate the occurrence or nonoccurrence, respectively, of erasures at specific locations.

A circuit for detection of erasures is included in the power-calculation unit. If an erasure occurs at the k'th location, a symbol α^k is calculated by the power-calculation unit and latched. The sequence of α^k's is fed to the polynomial-expansion circuit, to the power-expansion unit, and to the $\lfloor(d+\nu-3)/2\rfloor$ generator.

The power-expansion unit converts the α^k's into an erasure-locator polynomial $\Lambda(x)$, which is fed to the modified greatest-common-divisor (GCD) unit as one of its initial conditions.

A generator is used to compute $\lfloor(d+\nu-3)/2\rfloor$, where ν is the number of erasures and d = 1 + the number of parity symbols. The output is sent to the modified GCD unit and used as a stop indicator for Euclid's algorithm. The polynomial-expansion unit is used to compute the required Forney syndromes. The Forney syndrome polynomial $T(x)$ is fed to the modified GCD unit. The outputs of the modified GCD unit are the errata-locator polynomial, $\tau(x)$, and the errata-evaluator polynomial, $A(x)$. The error-correcting capability of the code is $\lfloor(32-\nu)/2\rfloor$.

The errata-locator polynomial $\tau(x)$ is fed to a Chien-search unit and to another unit for computation of

$$[x^{b-1}\tau'(x)]^{-1} = [x^{111}\tau'(x)]^{-1}$$

where b = 112. The errata-evaluator polynomial $A(x)$ is fed to the polynomial-evaluation unit. The $[(x^{111}\tau'(x)]^{-1}$ unit computes one part of the errata magnitude. The product of the outputs from the polynomial-evaluation unit and the $[(x^{111}\tau'(x)]^{-1}$ unit forms the errata magnitude.

The Chien-search unit is used to search for both the error and erasure locations. The architecture of the Chien-search unit is similar to that of a polynomial-evaluation

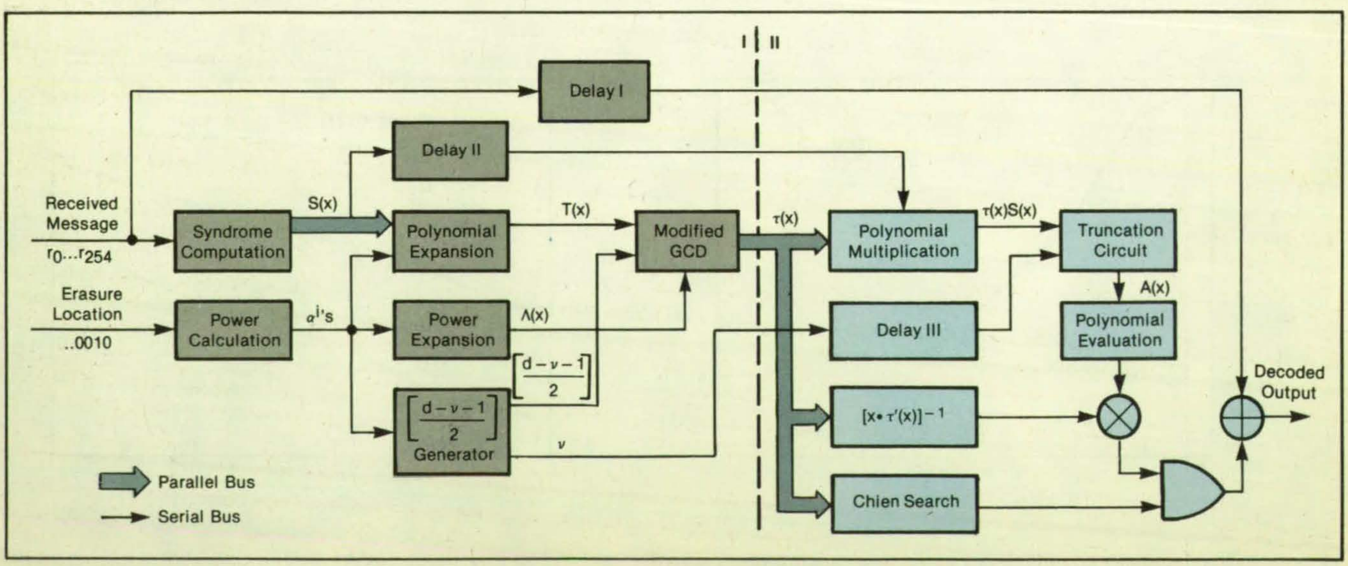


Figure 1. This **Pipeline Architecture of a Time-Domain Decoder** for a (255,223) Reed-Solomon code is based on a prior algorithm.

unit, except that there is a zero detector at the end in the Chien-search unit.

In comparison with the architecture illustrated in Figure 1, this improved architecture does not require the polynomial multiplication unit, delay II, delay III, and the truncation circuit. Thus, this new decoding algorithm is simpler and more suitable for implementation in very-large-scale integrated (VLSI) circuitry.

This work was done by T. K. Truong and I. S. Hsu of Caltech, W. L. Eastman of the Mitre Corp., and I. S. Reed of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 137 on the TSP Request Card.* NPO-17381

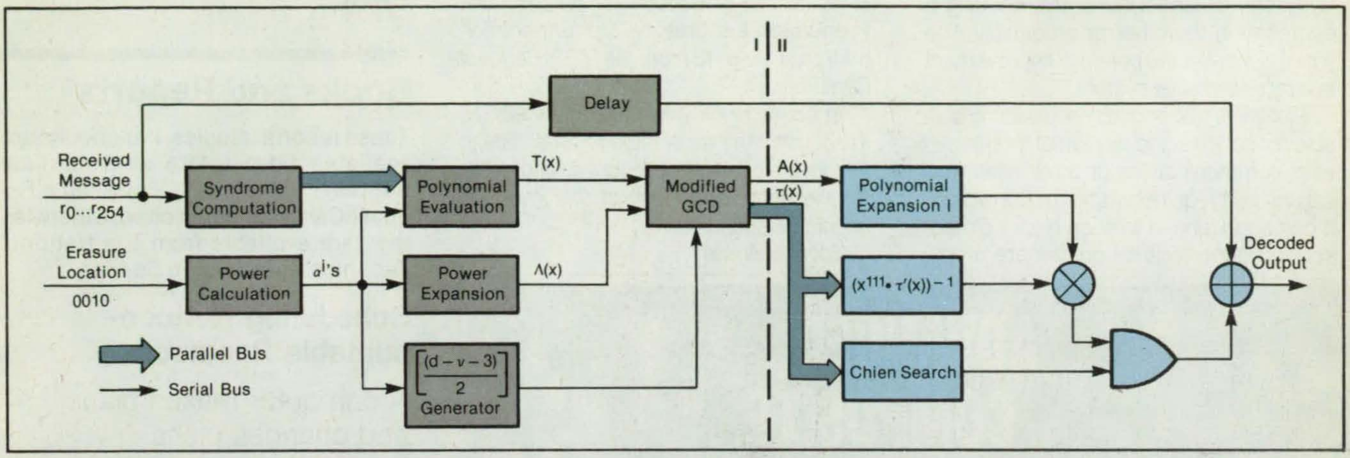


Figure 2. The **Improved Decoder**, based on the new algorithm, is less complex. In general, decoders according to the new algorithm can be made more regular, simple, and suitable for implementation in both VLSI and software.

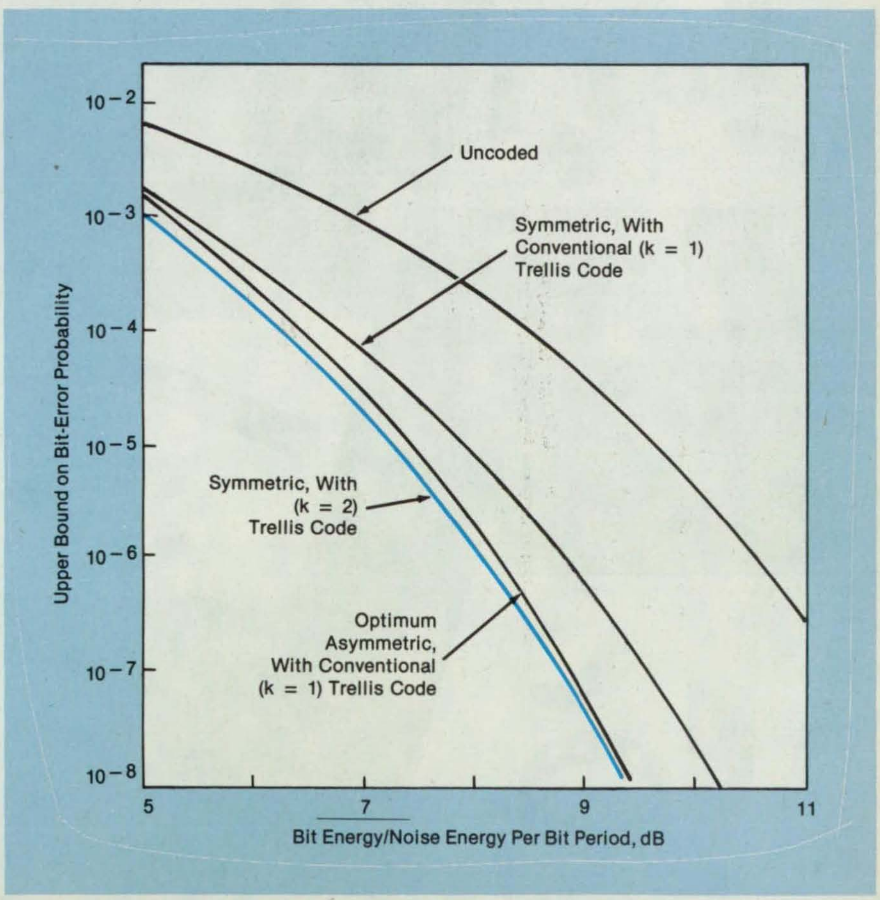
Multiple-Trellis-Coded Modulation

The theoretical gain over simple multiple-phase-shift keying is at least 2 to 3 decibels.

NASA's Jet Propulsion Laboratory, Pasadena, California

The multiple-trellis-coded modulation scheme combined with M-ary modulation has been shown theoretically to yield asymptotic gains in performance over that of uncoded multiple-phase-shift keying, while employing symmetric multiple-phase-shift signal constellations and avoiding code catastrophe. Although symmetric signal sets are optimum for uncoded systems, some previous attempts to improve performance with trellis-coded modulation had involved asymmetric signal constellations, with consequent increased sensitivity to phase jitter and a tendency toward code catastrophe, which is the merging of points in a constellation.

The scheme can be partly described in terms of a rate-$[nk/(n+1)k]$ code (where $k=1$ for conventional- and $k \geqslant 2$ for multiple-trellis-coded modulation) in a system that has a signal constellation (on the phase-angle diagram) of $M = 2^{n+1}$ points. During each transmission interval and for each trellis branch, kn bits enter the encoder and k symbols (one for each $n+1$ encoder-output symbols) leave the modulator. The throughput rate is still n bits per unit time per unit frequency, so that the bandwidth is no greater than that of a comparable 2^n-point uncoded system. The complexity, measured in terms of the number of states in the trellis diagram, is the same whether conventional or multiple trellis coding is used.



The **Performances of Four Modulation Schemes** are compared in terms of the upper bounds on their bit-error probabilities. All four involve quadrature-phase-shift modulation.

The gain in performance depends on the signal-to-noise ratio, the number of

trellis code states, and the number of modulation levels. One asymptotic measure of the gain in performance is obtained by comparing the minimum free Euclidean distance of the trellis code relative to the minimum distance of the uncoded modulation. In certain cases when $k \geqslant 2$, the free Euclidean distance increases, causing a decrease in the bit-error probability. The figure illustrates the potential improvement in a representative system.

Multiple-trellis-coded modulation is suitable for satellite and terrestrial-mobile/satellite communications or other communications that require burst-error correction. It can be extended to such higher dimensional modulations as quadrature amplitude modulation. While the required number of computations per branch is greater than in conventional trellis-coded modulation, this may be a small price to pay for the potentially-achievable performance gains, which are at least 2 to 3 dB.

This work was done by D. Divsalar and M. K. Simon of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 131 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for the commercial use of this invention should be addressed to

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Mail Stop 301-6
California Institute of Technology
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Pasadena, CA 91125

Refer to NPO-17100, volume and number of this NASA Tech Briefs *issue, and page number.*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Scheduling Nonconsumable Resources

A computer makes plans, and changes plans if goals change.

A user's manual describes the computer program SWITCH that schedules the use of resources — for example, electric power — by appliances that are switched on and off and use the resources while they are on. SWITCH plans schedules according to predetermined goals; it revises the schedules when new goals are imposed.

SWITCH starts by reading its input, which consists of the following:

- Descriptions of the initial state of the system under consideration and of expected changes in its state that are beyond the planner's control,
- Descriptions of the capabilities of the agents that will carry out the plan (that is, of changes that are under the planner's control), and
- Descriptions of the goals.

The statements that describe the goals are put into "LiteralTrays." A LiteralTray is a structure for storing a predicate — a statement about the state of the system under consideration. The LiteralTrays in turn are put into the "assertions" field of blank nodes, other data structures. A blank node does not correspond to a way to achieve a statement. The task of the planning program is to change all blank nodes into nodes of other types that do tell how their assertions will be achieved.

The program works by depth-first searching with strict chronological backtracking. At each stage of the construction of a plan, the program has a tentative partial plan. It computes alternative changes to the tentative partial plan, stores all but the first for possible future use, and tries to make the first alternative change, storing commands to undo it if it does not work. The program proceeds to evaluate the alternatives as necessary, sometimes interacting with the user.

A complete plan consists of a graph of nodes. Each nontrivial node describes an action that the agents must execute or an event that will happen, states when the action or event must or will begin, and contains a list of statements about the state of the system under consideration to be expected after the action or event.

The user's manual outlines the operation of the program; discusses its knowledge-base language; describes the construction of productions and scheduled events in the knowledge base; provides guidance in installing, setting up, and running the system; discusses replanning; and, finally, provides in an appendix an example of a session with the planner.

This work was done by Harry J. Porta of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the document, "SWITCH Users' Manual," Circle 135 on the TSP Request Card.*
NPO-16988

Performances of Fixed-Lag Phase-Smoothing Algorithms

Simulated performances differ from those predicted by linear theory.

A report discusses the performances of fixed-lag nonlinear smoothing algorithms applied to the estimation of the phase and frequency of a sinusoidal carrier signal with process phase noise and additive observation phase noise. An algorithm of the type considered functions as a suboptimal filter that operates on the received signal.

The algorithm is developed for a system in which the signal is sampled at discrete times. The process noise is assumed to be Gaussian with zero mean and to be independent of the observation noise. The nonlinear smoothing equations are derived in customary matrix-and-vector forms.

If the various gains in the system are represented in the equations by their steady-state values, the smoothing algorithm acts as a digital phase-locked loop followed by a postloop correction to the filtered estimates of the frequency and phase. The postloop correction can be implemented equivalently by a finite-impulse-response filter.

When the phase-locked loop operates with a high signal-to-noise ratio, the phase detector is approximately linear, and the smoothing equations reduce to the linear equations of an optimal smoother in an equivalent linear-signal model. The performance of such a smoother can be predicted by linear filter theory.

The performances of various smoothing algorithms were tested both theoretically and in numerical simulations. The performance predicted on the basis of linear estimation theory conforms with the corresponding results of the simulation both when the phase detector is assumed linear and when the nonlinearity of the phase detector is taken into account and the receiver operates at a high signal-to-noise ratio. Under these conditions the smoothing algorithm reduces the errors of estimation of phase and frequency to about 5.6 dB below those of an optimum phase-locked loop.

As the signal-to-noise ratio is reduced, the reduction in the estimation errors decreases. The reduction is greater in the presence of both process and observation noise than in the presence of observation noise only. Overall, taking account of the degradation caused by the nonlinearity in the performance of the filter in the phase-locked loop, the carrier-power-to-noise spectral density required to keep the phase-error variance within 0.1 is about 3.5 dB lower when the smoothing algorithm is used. The smoothing algorithm yields a similar decrease in the frequency-tracking error.

This work was done by Rajendra Kumar and William J. Hurd of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Fixed Lag Smoothers for Carrier Phase and Frequency Tracking," Circle 129 on the TSP Request Card.*
NPO-17202

Dry-Enzyme Test for Gaseous Chemicals

An easily administered test detects alcohol in breath.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simple, dry-chemical test detects ethanol in human breath. The method of the test can also be adapted to the detection of such toxic chemicals as formaldehyde in airstreams. The method can be used qualitatively to detect chemical compounds above a preset level; for example, ethanol above the legal level for driving. Alternatively, it can be used to indicate quantitatively the concentrations of compounds.

The method involves a dry enzyme and a color indicator. The enzyme catalyzes a chemical reaction of the compound of interest that changes the color of the indicator. Because the enzyme is dry, it has a longer shelf life than it does in aqueous solution. The method does not require a liquid solution, and therefore the test is easy and convenient to administer.

To make a breath analyzer, for instance, the reactants can be packaged in a small, disposable vial (see Figure 1). A human subject breathes into the vial, and a rapid change in the color of the contents of the vial indicates whether the subject is intoxicated.

The method is highly specific. The enzyme alcohol oxidase, for example, gives a positive reaction only to ethanol, methanol, formaldehyde, and hydrogen peroxide, and human breath is not likely to contain the latter three compounds. The enzyme does not react with tobacco smoke as some conventional chemical breath analyzers do. The method is also highly sensitive: it can detect concentrations of ethanol as low as 1 micromolar. It is fast, requiring only 1 to 3 minutes for a complete change of color.

The method can be adapted to detect any gaseous compound that can be transformed by enzymes to produce a change evident to the human eye or to an instrument. Other enzyme/indicator combinations include formate dehydrogenase for the detection of formate in the presence of a pH indicator, carbon monoxide dehydrogenase and a pH indicator for the detection of carbon monoxide, and esterases with pH indicators to detect carboxylic esters.

Dehydration of one or more enzymes is an essential step in the preparation of materials for the method. One or more of these enzymes are spread on such supports as alumina, glass beads, or cellulose particles and immobilized on the supports by drying. The concentrations, supporting material, and drying conditions are chosen to suit the application.

The method has been demonstrated in the qualitative detection of alcohol in air and breath. A mixture of alcohol oxidase, horseradish peroxidase, and 2,6-dichloroindophenol in water was dispersed on microcrystalline cellulose powder and left to dry at room temperature. The dry powder was placed in a glass vial.

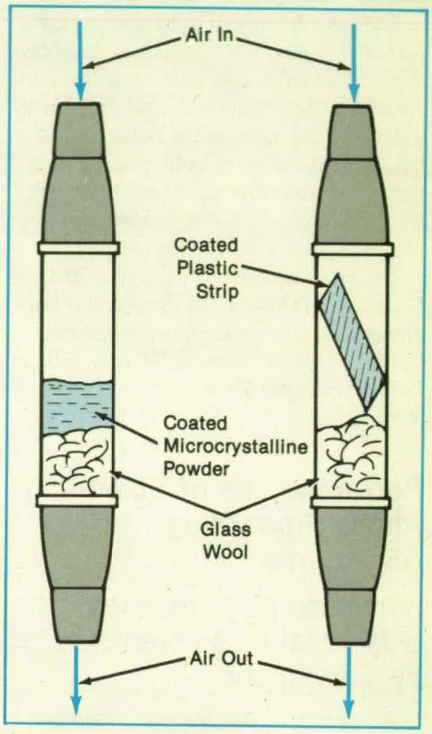

Figure 1. **Glass Vials** contain enzymes, indicators, and supporting material in two forms: loose powder for qualitative detection and a powder-coated transparent strip for quantitative detection. The vials measure 5 centimeters in length and about 0.6 centimeter in diameter.

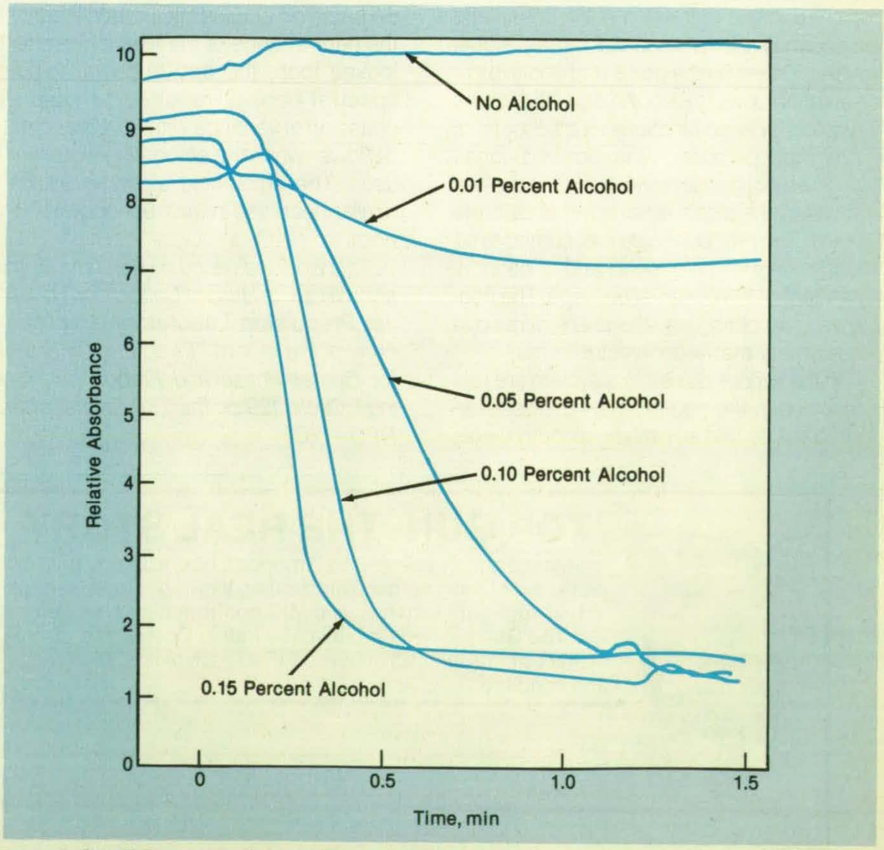

Figure 2. **Small Concentrations of Ethanol** in air produced by equilibrating the air with aqueous solutions of the concentrations shown resulted in rapid decreases in the relative absorbance of the material in the vial. The slopes of the plots and the final optical densities are functions of the concentration of ethanol.

SPECIAL REPORT

Electro-Optical Sensor Systems

Electro-Optics activities at ERIM involve sensors operating from the ultraviolet through the visible, infrared and into the millimeter wave region of the electromagnetic spectrum. Innovative sensing concepts and applications for both military and civilian missions are pursued both analytically and through actual hardware demonstrations.

Sensors, both ground-based and airborne, are designed, built, and tested to demonstrate new principles and to gather phenomenological data to optimize designs of future sensor systems.

Our calibrated, multispectral airborne line scan systems play a significant role in acquiring data for Government and Industry on a contract basis. Active E-O Sensors are another important part of ERIM's repertoire. Recently a 5-channel (0.53, 0.63, 0.82, 1.06 & 1.53 um) active system was designed and built for autonomous cross country vehicle operation.

ERIM's 3-D Laser Radar has been utilized as the "eyes" for both the Ohio State University's Six-Legged Walking Vehicle and the DARPA autonomous land vehicle operated by Martin Marietta Corporation. Also, under Army sponsorship, ERIM designed a system utilizing its 3-D sensor along with unique image processing architectures and algorithms to provide real-time control of a vehicle for autonomous road following. Current programs involve designing an imaging spectrometer for missile plume analysis and a system for incoming projectile detection. The Institute is currently working with industry, university, state and federal agencies to apply this sensor and processing technology to development of future highway systems known as Intelligent Vehicle-Highway Systems (IVHS).

IR&D

ERIM retains leadership in the E-O sensor community by maintaining a selected group of IR&D programs. Engineers with innovative ideas are encouraged to submit proposals for review by their peers and management. Current IR&D programs include: Multiple Target Tracking using a Laser System; Multimode Airborne, Active (Heterodyne) 3-D Sensor System; Sensor Polarization Studies, and other novel applications of diffractive optics and signal reconstruction.

Career Opportunities

ERIM is a growing, leading-edge, scientific research institute that performs contract research services for a variety of government, industry and university sponsors. Research at ERIM focuses upon remote sensing systems, devices, and techniques that span the electromagnetic spectrum. Within this broad research area, staff members employ their knowledge of modern electronics, optics, computer science, and infrared and microwave physics.

Newly-created opportunities are available for Research Engineers and Scientists in the following areas:

Systems:

- Digital signal processing
- Kalman filtering
- Motion compensation/navigation systems
- Documentation specialist
- Computer systems manager (networked SUN environment)
- Radar & EO Systems

Software:

- Real time embedded systems
- Software systems engineering/simulation/modeling
- User interfaces
- Software testability
- Ada, CASE tools, UNIX, X11, MIL-STD-2167A environment

Hardware:

- RF and microwave design, high speed digital and analog circuit design, microprocessor and interface technology, digital signal processor design, as well as system integration and flight test.

Previous experience with U.S. Government programs desirable, as is a BS, MS or PhD in Computer Science, Electrical Engineering or Mathematics.

For more information and prompt consideration, please forward your resume in strict confidence to: **ERIM, Human Resources Manager—NTB190, P.O. Box 8618, Ann Arbor, MI 48107-8618.**

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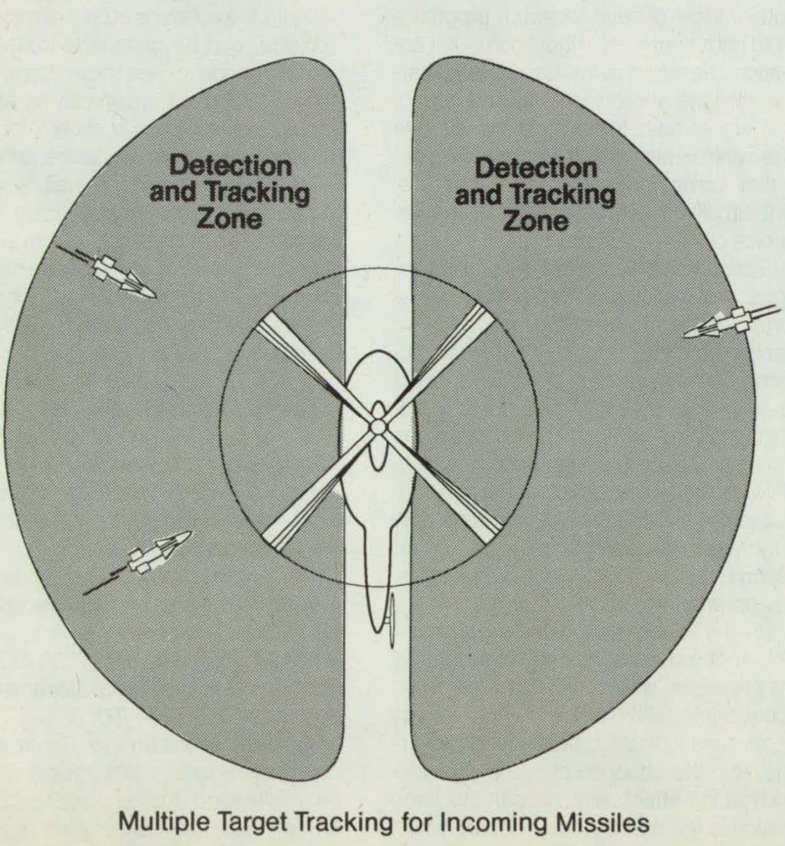

Multiple Target Tracking for Incoming Missiles

A stream of air containing ethanol vapor was passed through the powder. When the concentration of ethanol in the air corresponded to a concentration of 0.1 percent ethanol in water or blood (the maximum legal level for driving), the color of the powder changed from dark blue to pale violet in as little as 1 minute. The test was repeated on human subjects who had ingested alcoholic beverages. The breath was analyzed for a single exhalation in each case. The results were similar to those of the laboratory simulation.

The method has also been demonstrated in the quantitative detection of ethanol. Plastic strips coated with dried enzymes and cellulose powder were placed in vials, which were placed in a commercial gel densitometer and exposed to streams of air containing various concentrations of ethanol. The densitometer recorded the change in optical density at a wavelength of 605 nm (see Figure 2).

This work was done by Eduardo Barzana, Marcus Karel, and Alexander Klibanov of the Massachusetts Institute of Technology for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 124 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Books and Reports

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Flows in Model Human Femoral Arteries

Flow is visualized with dye traces, and pressure measurements are made.

A report describes an experimental study of flow in models of the human femoral artery. The study was conducted to examine the effect of the slight curvature of the artery on the flow paths and the distribution of pressure.

Two full-scale models were used: one made of glass tubing and the other of flexible plastic tubing. Both included curved sections having a radius of curvature of 20 cm and subtending an angle of 40°. Small holes 0.051 cm in diameter admitted dye to a sucrose water solution (which has the kinematic viscosity of blood) flowing along the glass model so that flow paths could be visualized. Similar holes in the plastic model lead to external pressure transducers. The internal diameter of both models was 6.35 mm. Long, straight sections of tube preceded and followed the curved sections.

The pattern of steady flow in the glass model was found to be like that in coiled pipes. A double helical pattern was observed, with the streamlines in the vicinity of the wall converging stably along the tube at the inner curvature. The helical or swirl angle was found to increase with the rate of flow.

Pressure was found to decrease more steeply with increasing distance in the curved section. This indicates that centrifugal effects increase with increasing flow. In both pulsatile and steady flows, the pressure drops were attributable mostly to viscosity. In pulsatile flow, the time-averaged pressure drops were about the same as in steady flow.

This work was done by Lloyd H. Back and Eug Y. Kwack of Caltech and Donald W. Crawford of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Flow Measurements in a Model of the Mildly Curved Femoral Artery of Man," Circle 77 on the TSP Request Card.*
NPO-17599

Computer Animation in Perception Research

The artificiality of images is apparent to subjects and may influence experimental results.

A report evaluates computer-generated animation in reseach on the perception of motion. Most of such research programs could not be pursued without computer animation, the report notes. Computer-generated displays afford variability and control that are almost impossible to achieve otherwise. However, the medium is limited in that computer-generated images present simplified approximations of the dynamics of natural events.

Computer animation has several advantages. It is easier to generate displays by computer than to build movable physical mechanisms that produce the desired motions. Computers can be programmed easily to display events that appear to violate the laws of physics. This ability proves to be highly useful in assessing visual sensitivity to natural dynamics and can be duplicated by real objects only with great difficulty. Moreover, with computer-generated displays, researchers always know the display parameters exactly.

On the other hand, whenever people look at computer-animated displays, they are presented with conflicting information about depth relationships. All the primary depth cues indicate a two-dimensional image, and the absence of motion parallax adds to the effect. At odds with this information is the motion in the display, which indicates a three-dimensional structure.

There are other disadvantages as well:

- An object does not appear to be located on the monitor screen; rather it appears to be somewhere behind the screen.
- Unlike natural scenes, computer displays subtend a limited area of an observer's field of view. The observer has the clear sensation of viewing a window on a scene rather than the scene itself.
- Rapidly moving objects have an unnaturally clear and abrupt appearance that gives rise to a stroboscopic effect, whereas the images on movie films have a natural-looking blur. This disadvantage of computer animation can be overcome with blurring algorithms, but at present these algorithms are too complex for use in real time.
- Realistic texture and shading are difficult to achieve.
- At present only the simplest dynamic events, like collisions of balls or rotations of objects, can be generated from mathematical models. Even these simple events are often based on simplifying assumptions — that friction is absent, for example, or that particle mechanics, rather than solid-body mechanics, prevail.

The report recommends caution in making generalizations about human sensitivity to natural events from studies based on computer-animated displays. Such studies should be accompanied by investigations based on natural objects.

This work was done by Mary K. Kaiser of **Ames Research Center** *and Dennis R. Proffitt of the University of Virginia. Further information may be found in NASA TM-88335[N87-14845/NSP], "Applications of Computer-Graphics Animation for Motion-Perception Research."*

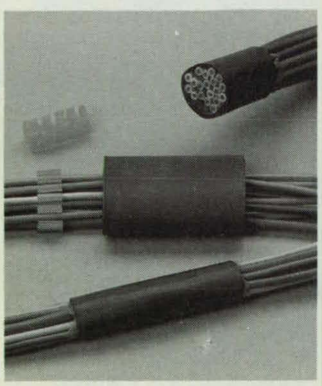
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 16]. Refer to ARC-11774.

New on the Market

The **GPIB-SCSI controller** from National Instruments, Austin, TX, turns any computer or workstation with an SCSI port into an IEEE-488 (GPIB) instrument controller. The GPIB-SCSI is an 8-bit microcomputer that connects to any SCSI port and transparently converts SCSI protocol into GPIB protocol to control up to 14 GPIB instruments. It has a built-in DMA controller for transferring data at rates up to 900 kbytes/sec.
Circle Reader Action Number 786.

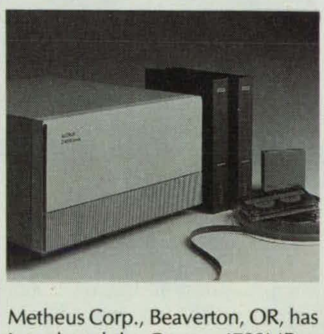
SimTool, a **fluid/thermal system simulation and analysis program** from Mainstream Engineering Corp., Rockledge, FL, enables engineers to perform preliminary design calculations and detailed analysis of single-phase, two-phase, or multi-component two-phase fluid systems. The program, which contains a library of over 1000 fluids, performs both steady-state and transient analyses. An MS-DOS demonstration version that allows engineers to evaluate Simtool's performance and capabilities is available.
Circle Reader Action Number 778.



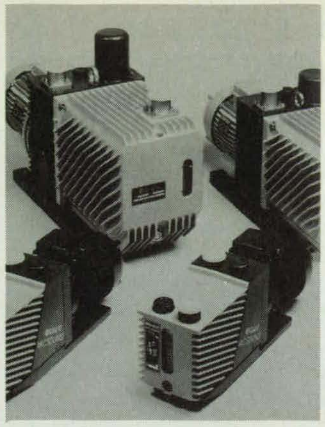
The RayBlock™ **sealing system** from Raychem Corp., Menlo Park, CA, protects electrical systems against moisture and corrosion. The product — which combines Raychem's heat-shrinkable tubing with a comb-like "profile" of hot-melt adhesive — seals around and between the individual wires in a bundle, preventing water from entering and migrating along bundles to sensitive connections. The Rayblock system also provides strain relief and withstands extreme temperatures (-40° to +105°) and vibration.
Circle Reader Action Number 784.

Visual Research Corp., Passaic, NJ, has introduced **a 3D stereoscopic TV camera system** compatible with all RS-170 video devices — including VCRs, monitors, optical discs, and microfloppies. The BTX-3D system features user-selectable 2D or 3D viewing and/or recording, a split screen function for optical alignment of cameras, and optional character overlay for electronic annotation of images. It is available with a variety of viewer glasses.
Circle Reader Action Number 792.

American Small Business Computers, Pryor, OK, has introduced ModelCAD, a **computer-aided design (CAD) system for modelers**. ModelCAD is used to create and edit drawings, which can then be saved on a disk or output to dot-matrix printers, laser printers, or plotters. The program can perform complex calculations and measurements — such as area, distance, and center of gravity — and offers advanced features including auto-dimensioning, layering, and full zoom and rotate capability. Priced at $99, ModelCAD runs on IBM PC and compatible computers.
Circle Reader Action Number 782.

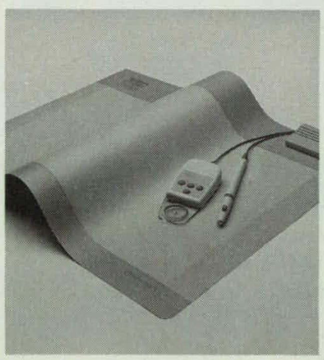


Metheus Corp., Beaverton, OR, has introduced the Omega 4700MR, a 32-bit, VME-based **graphics display controller** with viewable resolutions from 1280 x 1024 up to 2048 x 2048. It consists of triple eurocad (9U) VME-based modules housed in a free-standing chassis. Together, these modules provide a display processor, up to four 8-bit frame buffers, a multi-frequency video generator, and a multiprocessor transform and clipping accelerator with display list memory.
Circle Reader Action Number 780.



Galileo Vacuum Systems, Somers, CT, has introduced the Vacsound line of portable **rotary vacuum pumps** for industrial applications. The lightweight, quiet pumps provide a low working temperature and feature a built-in lubricating pump for optimum operating safety and high pumping speed at working pressures from 1000 mbr down. They also have hydraulically-operated isolation valves to avoid pressure rise or suction line contamination.
Circle Reader Action Number 800.

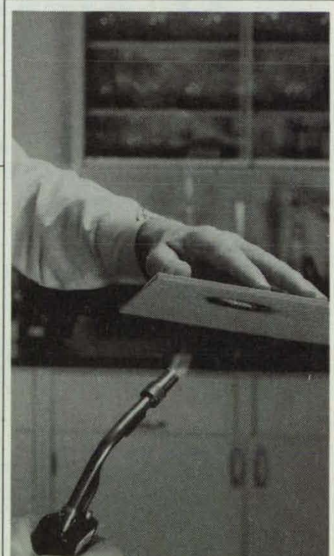
Aspex Inc., New York City, is offering a **free videotape demonstrating PIPE®, a high-performance parallel processor** tailored for complex imaging applications such as autonomous vehicle guidance, high-speed industrial inspection, medical image processing, target tracking, and reconnaissance image analysis. Using real-world examples, the 17-minute video demonstrates PIPE's many computational capabilities, including flow, object tracking and recognition, edge detection, pattern and template matching, and three-dimensional model matching.
Circle Reader Action Number 798.



The GridMaster™ from Numonics Corp., Montgomeryville, PA, is a $^1/_{32}$" thick, flexible **digitizer tablet** designed for graphics applications such as CAD/CAM, desk-top publishing, and business and presentation graphics. It features 1000 lines per inch resolution and pen-tilt correction, resulting in an accuracy of 0.010". The tablet operates with all graphics software and is IBM PC/XT/AT and Macintosh compatible.
Circle Reader Action Number 790.

Visix Software Inc., Arlington VA, has introduced Looking Glass®, an icon- and mouse-driven **graphical user interface to UNIX** for X Window system terminals, technical workstations, and high-end PCs. Comprising more than 300,000 lines of code, Looking Glass enables users to navigate the UNIX file system; manage files and directories; launch and manage applications; and perform system and network administration. It also offers an extensive, context-sensitive help system.
Circle Reader Action Number 796.

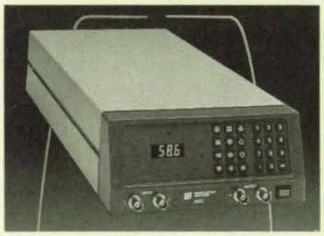
The C60-600 series **motion controller** from Icon Corp., Woburn, MA, features up to four coordinated microstepper drives. The system will drive up to four motors with 7 amps per phase, and offers an X10 microstep feature, MOSFET drive transistors, and smooth high-resolution/motion with a choice of motor designs.
Circle Reader Action Number 788.



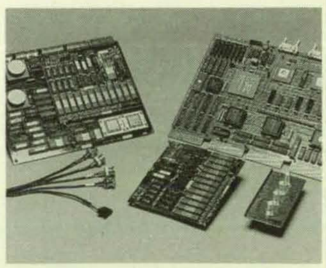
PYROPEL® from Albany International, Mansfield, MA, is a lightweight, high-temperature, **fibrous panel material** that can be formed into rigid, self-supporting ducts, sidewall panels, temperature guards, and fire stops. It does not burn, melt or drip and emits almost no smoke. Pyropel can be used continuously from -300° to +600° F and is unaffected by most chemicals.
Circle Reader Action Number 794.

New on the Market

The Model 9002 two-channel **filter instrument** from Frequency Devices Inc., Haverhill, MA, can set and save eight six-parameter configurations per channel for up to five years. Each channel is continuously tunable — with no range switching — over a 1,024,000:1 frequency range of 0.1 Hz to 102.4 kHz. The instrument is programmable by front-panel key pad or remote computer. Applications include interactive anti-aliasing, vibration and signal analysis, geophysical measurements, and industrial process control.
Circle Reader Action Number 768.



Aeon Systems Inc., Albuquerque, NM, has introduced the VIVA family of intelligent high-performance **bus-to-bus links** for Q-bus, VAXBI, VMEbus, and MultiBUS II systems. The links allow system designers and integrators to cost-effectively create distributed solutions to real-time acquisition, control, and simulation problems. The VIVA link consists of a pair of bus-specific boards (link controllers) and either a coaxial or fiber optic cable assembly. It supports as many as 1024 logical connections between applications running on the distributed hosts.
Circle Reader Action Number 766.



Invoil 46, a synthetic **diffusion-pump fluid** from the Inland Vacuum Division of IVAX Industries, Churchville, NY, meets the performance requirements of such applications as optical coatings, evaporation and sputtering, vacuum metallurgy, leak detection, and mass spectrometry. The fluid offers high thermal stability and radiation resistance, and can attain untrapped ultimate pressures near 10^{-8} Torr. Its ability to recover from accidental exposure to the atmosphere during normal operation is similar to that of silicone diffusion-pump fluids.
Circle Reader Action Number 774.

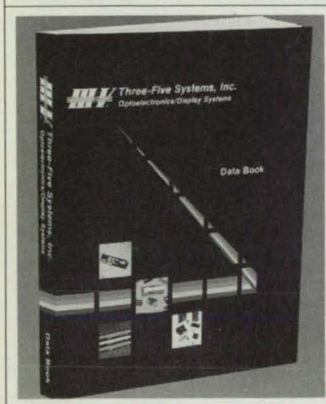
Intel Corp, Santa Clara, CA, has introduced a **C-language tool kit** for developing new applications and porting existing applications to the i860 microprocessor, a 64-bit CPU designed for high-end technical and scientific computing. It allows programmers to write applications for OS/2 environments that combine a 386 or i486 microprocessor and an i860 application processor, including IBM's new PS/2 Wizard. The kit includes the i860 High C Compiler and Run-time Library from Metaware, as well as an assembler, linker, simulator, debugger, and scalar math library.
Circle Reader Action Number 776.

Ready Systems, Sunnyvale, CA, has introduced the **VRTX32 real-time environment** on the IBM PC/AT/XT and compatibles. The new product, VRTX-PC, gives embedded systems designers working with a PC the capability to use their machine as both the development platform and the embedded computer. It enables a PC to control demanding, time-critical applications where deterministic operating system performance is mandatory, such as in industrial control, factory automation, robotics, and medical instrumentation. VRTX-PC includes the VRTX32 (real-time kernel), RTscope (real-time debugger), IFX (input/output file executive), RTL (run-time library), and PCX (PC support executive).
Circle Reader Action Number 770.

The VideoProbe 2000, an electronic imaging **borescope** from Welch Allyn's Inspection Systems Div., Skaneateles Falls, NY, is designed to inspect deep, remote equipment cavities and inside long piping. Suited for applications in the power generation, aerospace, and process industries, the new VideoProbe system is a flexible borescope with pneumatic muscles for articulation to bend around corners as it travels internally through equipment and piping. A miniature microchip camera located at the tip of the probe transmits images to a video screen, allowing nondestructive, internal examination of equipment for defects, foreign objects, fuel leaks, discoloration, and deterioration.
Circle Reader Action Number 772.

New Literature

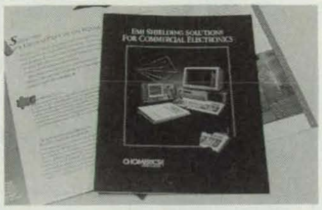
A four-color capabilities brochure from Coating Sciences Inc., Bloomfield, CT, spotlights the company's line of **adhesive films, foams, and tapes**, including pressure-sensitive adhesive-coated products and transfer films. The eight-page publication describes applications in the medical, automotive, electronics, sound control, product assembly, graphic arts, and construction fields. Coating Sciences' integrated manufacturing capabilities and technical expertise are also discussed.
Circle Reader Action Number 702.



More than 450 products are featured in a new **optoelectronics/display systems** catalog from Three-Five Systems Inc., Phoenix AZ. Standard product families highlighted include numeric, alphanumeric, and bar graph displays with onboard drivers; multiple digit numeric displays; 880 and 940 nm infrared emitters/detectors; LED lamps, digits, and light blocks; and optocouplers. The 400-page publication also features a comprehensive application note section.
Circle Reader Action Number 704.

A free **fiber optics and data communications handbook** from the Automatic Tool and Connector Co., Union, NJ, provides a primer on fiber optics; a selection of connectors, cables and assemblies, splices, and tools; and a glossary of terms used in the fiber optics and data communications field. The handbook features technical charts illustrating typical optical fiber characteristics, transmission loss for various transmission links, cable strengths, jacketing materials, and military specifications.
Circle Reader Action Number 708.

Photometrics Ltd., Tucson, AZ, is offering a free 30-page booklet which describes high linearity and dynamic range applications for **CCD imagers**. The booklet discusses CCD performance limitations together with calibration and noise reduction techniques, and presents the advantages of slow-scan CCD cameras for scientific applications.
Circle Reader Action Number 712.



A four-color brochure from Chomerics Inc., Woburn, MA, describes **electromagnetic interference (EMI) shielding products**, including gaskets, conductive paints, cable jackets, foil tapes, ground straps, and absorbers. The free publication also highlights Chomerics' radiation testing services, including VDE, CISPR 22, VCCI, and TEMPEST testing.
Circle Reader Action Number 710.

The 1990 Vibration Handbook from Spectral Dynamics, San Diego, CA, features sections on DYMAC machinery monitors and transducers, instruments for dynamic analysis, multi-channel real-time data acquisition and analysis systems, and computer-aided testing solutions. Offered free of charge, the handbook presents short courses in vibration analysis, discusses the company's engineering capabilities, and includes a glossary of vibration analysis terms.
Circle Reader Action Number 706.

Analog Devices Inc., Norwood, MA, is offering **Digital Signal Processing in VLSI**, a 614-page handbook on applications, theory and integrated circuits for digital signal processing (DSP). It merges the concepts of sampled signals and systems with software algorithms and hardware for processing of real-world signals. The book is divided into two parts: fundamental DSP principles, and their applications.
Circle Reader Action Number 714.

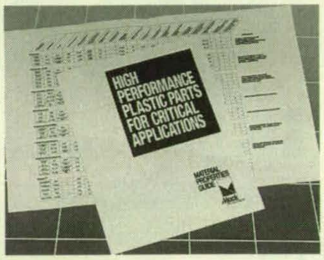
New Literature

Key Contacts in Advanced Aerospace Materials, a 220-page publication listing more than 3500 engineers, buyers, program managers, and department heads who work with or manage the use of fiber composites, ceramics, and advanced metals, is now available from Whitney-Stearns Corp., Irvine, CA. All major defense, aircraft, missile, and airline companies are described, along with their subcontractors. The publication, which sells for $225, lists each individual's project, title, phone and telefax number, and mail stop.
Circle Reader Action Number 718.

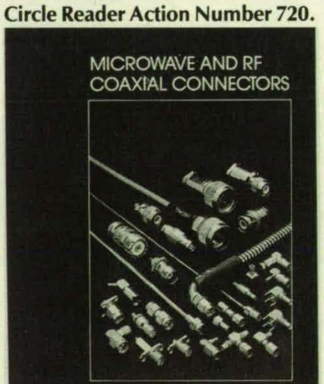
A **cryogenic accessories** catalog from Lake Shore Cryotronics, Westerville, OH, features current sources, digital thermometers, magnetic field Hall sensors, thermocouples, wires and coaxial cables, metals and tubing, vacuum components, and assemblies. The catalog combines technical product information and application notes in one convenient source.
Circle Reader Action Number 716.

A new brochure from Dow Corning Corporation describes the features and properties of **fluorosilicone products** for aerospace/defense applications. Fluorosilicones are designed to withstand continuous contact or immersion in jet fuels and solvents and the below-freezing temperatures of high altitudes. They are unaffected by continuous exposure to temperatures up to 260° C. These features make them useful for sealing and coating aircraft integral fuel tanks and ground-support fuel-handling systems.
Circle Reader Action Number 724.

A free materials properties guide from Mack Plastics Corp., Bristol, RI, provides an overview and comparison of **high-performance plastics and metals**, including polyimide, polyamide-imide, polyetherimide, polyphenylene sulfide, liquid crystal polymer, and aluminum, titanium, bronze, steel, and cast iron. It lists major characteristics for each plastic or metal such as specific gravity, tensile and compressive strength, modulus, coefficient of thermal expansion, temperature range, and resistance to fuels, oils, and solvents.
Circle Reader Action Number 722.



Radiall Inc., Stratford, CT, is offering a 280-page catalog featuring **microwave and RF coaxial connectors**. Product highlights include miniature, microminiature, subminiature, standard, and high-voltage connectors; coaxial terminations in the DC to 1 GHz and DC to 26.5 GHz frequency ranges; and coaxial attenuators in power ratings from 2 to 65 watts. Electrical, mechanical and environmental specifications are provided for all connectors, as well as information on accessories, mounting, and installation.
Circle Reader Action Number 720.



A line of **non-contact proximity sensors** including inductive, capacitive, magnetic, and NAMUR types is described in a 48-page catalog from Hubbell Industrial Controls Inc., Madison, OH. Designed as a sensor selection, installation, and testing aid, the catalog offers wiring connection data and diagrams, performance standards, and dimensional elevation drawings of each sensor style, as well as information on sensing range, material motion, and mounting.
Circle Reader Action Number 726.

Subject Index

NASA's Mission To Planet Earth
(continued from page 13)
tists on hundreds of research teams. The volume of data planned for transmission is approximately 20 million bits/sec. This will accumulate at a terabit every day, which is equivalent to about a million pictures every day or five billion in the course of the project. This collosal volume of data must be converted, reduced, catalogued, and then distributed.

There are currently about 600 scientists working on EOS. They come from government laboratories, universities, industry, and non-profit institutes. They come from a variety of countries at all economic levels, and they represent every branch of science studying the Earth — from the microscale to the global scale. They cover experimental work and theoretical modeling, instrument development, calibration, data reduction, and science management.

A Major New Initiative

EOS is one of NASA's major new proposed initiatives. Goddard Space Flight Center will be responsible for managing the project, which is scheduled to begin its construction phase in 1991. Potential contractors have been alerted and some initial studies of long-term problem areas are under way.

EOS and its related projects in Mission To Planet Earth will result in an enormous growth in technology over the next decade. The demand for more sensitivity, longer-lasting hardware, unusual cooling capability, special optics, and data management will advance the state of the art significantly. Spinoffs from EOS projects will benefit other human endeavors in space and on the ground.

NASA has both an opportunity and a responsibility to contribute to the goals of the EOS mission. The responsibility is to work as one member of a larger effort that will permit mankind to come to grips with the major socioeconomic world problem of the next century. The opportunity is to apply its unique talents in exploration, science, space technology, telecommunications, quality assurance, and project management to a task that will expand the capability and elevate the reputation of the agency beyond anything it has done in the past. NASA's future is strongly tied to its ability to respond to this extraordinary opportunity. ❑

About The Author

Dr. Gerald A. Soffen is Associate Director for Program Planning in the Goddard Space Flight Center's Space and Earth Sciences Directorate and also Senior Project Scientist for NASA's Earth Observing System. Prior to his coming to Goddard, Dr. Soffen was the Director of Life Sciences at NASA Headquarters in Washington, DC. He holds a PhD in Biology from Princeton University.

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Mission Accomplished

Manufacturers across a wide range of industries are employing machine vision systems to help improve quality standards in the fit and finish of their products. Most of these systems do not have the sensitivity, however, to detect all of the imperfections their users would like to catch and correct.

Diffracto Ltd., Windsor, Ontario, has developed an innovative technique called D Sight™ that reveals tiny flaws previously difficult or impossible to observe. The D Sight system can be used to inspect both flat and curved surfaces to locate such imperfections as dents, dings, waviness wrinkles, and blisters. It detects and magnifies localized defects measuring less than one thousandth of an inch.

D Sight: A new tool for quality control

According to industry tests, D Sight can identify 94 percent of the defects when inspecting stamped sheet metal, as compared with only 50 percent for traditional flaw detection methods such as visual inspection.

The basic system, which sells for about $100,000, consists of a solid-state camera equipped with a quartz halogen lamp; a retroreflective screen; and an image processing computer. The camera photographs the part being studied while the retroreflective screen bounces light off the surface to highlight defects. The resulting image is computer-analyzed and the discovered defects projected onto a video monitor for comparison with a stored "master" image of an acceptable part. Also included with the system is a hard copy printer which provides documented evidence of product quality and proof of inspection.

For the D Sight technique to work, the target surface must be reflective. Since some surfaces — such as unpainted sheet metal — are not reflective enough, Diffracto has created a relectivity enhancing process which involves wiping an oil- or water-based compound on the surface.

D Sight is a spinoff from the space shuttle program. Diffracto was licensed to develop commercial applications for the vision guidance system of the shuttle's remote manipulator arm. While experimenting with the vision system, Diffracto engineers noticed the phenomenon of reflected light from the target material. This led to a research and development effort that produced the first commercial D Sight model.

Thus far Diffracto has sold 24 units — most to automakers such as Ford and General Motors, who employ D Sight to inspect body panels and windshields, and to check "first articles" for die-related defects. Plastics manufacturers use the system to determine what temperatures, pressures, and materials will produce the best quality surfaces. Moreover, several aircraft manufacturers have bought units to inspect aircraft composite skins.

"Companies are using the D Sight technique for problem-solving," said Walter Pastorius, a Diffracto spokesman. "By capturing an image of a part after each operation in the manufacturing process, a company can see how the different operations change the part's surface, which enables them to pinpoint problem areas in the process that need fixing." ❑

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